# PROJECT MANAGEMENT PRACTICES AND INFORMATION FLOW IN THE PRECONSTRUCTION STAGE OF MASS TIMBER CONSTRUCTION PROJECTS

By

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ABSTRACT

An effective and environmentally friendly substitute for traditional steel and concrete building is mass timber construction, or MTC. Despite its increasing use, the preconstruction stage of mass timber projects poses difficulties because of the coordination between different teams, the integration of digital workflows, and the complexity of procurement. This research aims to investigate project management practices during the preconstruction phase of mass timber construction projects, focusing on the flow of information, stakeholder roles, and decision-making processes. The study employs a qualitative exploratory approach, utilizing literature review, industry interviews, and case studies to identify key stakeholders, their interactions, and the efficiency of information exchange. The findings will contribute to developing an optimized information flow model that enhances coordination and project efficiency in mass timber projects. By addressing existing gaps and challenges, this research seeks to provide industry practitioners with insights into best practices for improving preconstruction management in mass timber construction.

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# CHAPTER 1: INTRODUCTION

## Background

The adoption of mass timber as the main building material has significantly changed the U.S. construction industry in over a decade. From 2015 to 2020, mass timber influenced modern architecture and construction techniques, successfully addressing development, sustainability, and climate change. The idea of mass timber is not new. Building codes include components like nail-laminated timber (NLT) and glue-laminated timber (GLT), which have been used in construction for a long time. However, since 2015, there has been an upsurge of these materials, particularly NLT, and greater acceptance of GLT for larger items. Given its strength and stability, cross-laminated timber, the true standout-has been utilized across Europe for over twenty years. Since CLT hit the market in the United States, greater buildings which were before difficult to construct using wood has been made feasible (Woodworks, 2021).

## Types and Applications

Mass timber encompasses several types of engineered wood products, each with unique properties and applications:

Cross laminated Timber, or CLT, is a strong wood product made by gluing layers of lumber together. Each layer is placed at a right angle to the others, which makes the panels very strong and stable. These panels can be big, usually ranging from 4 to 12 feet wide and 20 to 60 feet long, depending on what the makers decide and what the building project needs. CLT is great for many parts of a building like floors, roofs, and walls because it is strong and can cover larger areas without bending. CLT is commonly made from solid sawn softwood lumber, including spruce-pine-fir (SPF), Douglas fir and southern yellow pine. The construction industry in Europe have been using CLT for more than 20 years, it is still quite new in the U.S. It was officially recognized for use in certain types of buildings by the 2015 building codes. This means that now, more buildings can be made with CLT, which is good news for making strong, wood-based buildings.(WoodWorks, 2021)

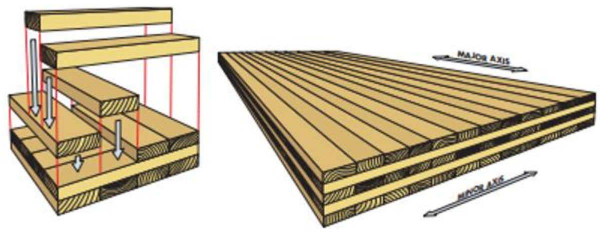


*Figure 1CLT panel assembly (Woodworks 2021)*

Nail-Laminated Timber**,** or NLT, is a type of mass timber made by stacking 2x4s or 2x6s on edge and nailing them together to form big panels. These panels, usually made in sizes from 4 to 8 feet wide and 16 to 40 feet long, can be built off-site or directly at the construction site. NLT is used for building floors and roofs but can also be used for walls and parts of stairs and elevators. (WoodWorks, 2021)

*Figure 2 NLT panel (Woodworks 2021)*

Dowel-Laminated Timber (DLT) is becoming popular in the U.S. because it works well with modern machinery and is made entirely of wood. DLT panels are created by pressing solid wood boards together with wooden dowels, providing stability and the option to add special designs or acoustic features. These panels are great for floors and roofs, offering an eco-friendly building option that is easy to adjust on-site(WoodWorks, 2021).

*Figure 3 DLT panel (Woodworks 2021)*

Structural Composite Lumber (SCL) is a type of engineered wood made by layering wood veneers or strands with glue to form large blocks, then cutting these blocks into specific sizes. The wood layers go in one direction, making SCL very strong and consistent in size and strength. It is commonly used for beams and columns in building construction(WoodWorks, 2021).

Laminated veneer lumber (LVL) is produced by bonding thin wood veneers with the wood fibers primarily oriented along the strong axis.

*Figure 4 LVL beams (Woodworks 2021)*

Laminated strand lumber (LSL) is made from flaked wood strands that have a length-to thickness ratio of approximately 150.

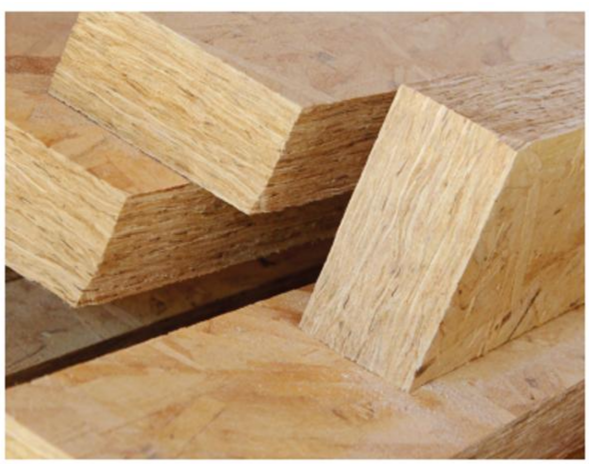

*Figure 5 LSL beams (Woodworks 2021)*

Parallel Strand Lumber (PSL) is made by cutting veneers into long strands and arranging them along the material's strongest axis. The strands used in PSL have a length-to-thickness ratio of about 300, ensuring they provide significant strength and durability for construction purposes (WoodWorks, 2021).

*Figure 6 PSL beams (Woodworks 2021)*

Glue-laminated timber, known as glulam for columns and beams and GLT for planks like decking, is made by stacking solid sawn lumber pieces with adhesive between each layer. Special jigs help create various shapes and curves for different architectural needs. In mass timber constructions, glulam is more commonly used than GLT, with design considerations including stress factors, wood species, and grade (WoodWorks, 2021).

*Figure 7 Glulam beams and GLT plank (Woodworks 2021)*

**Properties and Performance**

Natural elements like flavonoids and tannins that exist in mass timber products improve their resistance to pests and decay. However, the type of wood and the environment around it may impact the amount of time it endures. Preservative treatments are needed for safeguarding the wood in humid or rainy conditions. Methods such as Chemical Modification (CM), Thermal Modification (TM), and Preservative Treatment (PT) are employed to improve resistance to biological deterioration and moisture. In harsh conditions, these treatments aid in preserving the longevity and structural integrity of bulk timber (Ayanleye et al., 2022).

When exposed to fire, mass timber products develop a protective char coating, which is the main reason for their natural fire resistance. To assist the structure, fulfill the fire resistance requirements of building codes, this char functions as an insulator, protecting the timber's core, slowing combustion, and maintaining the structure's integrity for a certain period. In addition, it is demonstrated by means of strict fire testing and experimental studies that solid design and the use of protective cladding or fire-retardant treatments, which block oxygen and reduce the wood's potential to ignite a fire, may significantly improve the fire resistance of mass timber (Abed et al., 2022; Mitchell et al., 2023).

Because of its flexibility and low weight, mass timber, especially Cross-Laminated Timber, or CLT, is ideally suited for regions that are vulnerable to earthquakes and strong winds. Mass timber constructions may effectively disperse wind energy and minimize seismic forces because of these qualities, which are essential for preserving structural integrity during such events. In addition, mass timber's modular design can be improved for better stability against wind-induced lateral forces. Since wood is inherently elastic but has strong, ductile connections, buildings in earthquake-prone areas can absorb seismic energy, minimizing damage and increasing safety. Because of these characteristics, mass timber is a sturdy and secure alternative for building under harsh environmental circumstances (Abed et al., 2022).

## Sustainability and Environmental Benefits

### Carbon Sequestration

Together, (Cover, 2020; Taylor et al., 2023; Whelan, 2021) they offer a strong framework for understanding the several benefits of mass timber in carbon management. MTC has grown into a sustainable option for modern buildings, greatly aiding in carbon sequestration and providing a workable solution to urban growth while addressing climate concerns.

Mass wood products naturally retain carbon that has been absorbed throughout growth. The wood retains this biogenic carbon for the duration of the building's existence, and maybe for an extended period if the wood is recovered. (Cover, 2020) explains that since renewable biomass provides most of the energy used to produce wood goods, they require less energy to produce than more conventional building materials like steel or concrete. Because of this lower embodied energy, structures made of mass timber have a far less carbon impact.

Furthermore, (Taylor et al, 2023) researches the potential economic benefits of carbon sequestration through carbon credits. By substituting more carbon-intensive materials with mass timber, it suggests that the carbon stored, and the emissions avoided could be examined and traded as carbon offsets. This system could encourage the use of sustainable building practices and help mitigate climate change by making bulk timber more appealing to investors and developers.

Furthermore, the example research from the Pacific Northwestern United States shows that mass timber buildings have a significantly lower overall carbon footprint than concrete buildings (Liang et al., 2021). It measures the amount of carbon stored in mass timber as well as the lower emissions from its manufacture and recyclability at the end of its useful life. Considering both operational and embodied carbon, this study shows that mass timber buildings have 12% lower greenhouse gas (GHG) emissions over a 60-year period than concrete structures.

**Reducing greenhouse gas emissions**

The use of mass wood in construction is a significant step in reducing greenhouse gas (GHG) emissions and enhancing sustainability. The advantages of mass timber are further supported by the findings of (Damtoft et al. 2008) and (Abed et al. 2022). When taken as a whole, these resources offer a thorough analysis of how mass timber works as a successful substitute for conventional building materials.

Embodied Emissions: Throughout the building's history, mass timber is renowned for its ability to preserve carbon during its growth phase. The embodied emissions associated with building materials are significantly lowered by this approach. Mass timber provides a more sustainable option to traditional materials like steel and concrete, which require significant energy inputs and produce significant greenhouse gas emissions, by reducing the carbon footprint from the very beginning of production (Abed et al., 2022).

Operational Energy Efficiency: As mass timber has excellent natural insulating characteristics, buildings made of this material are known for having superior energy efficiency. Because of this efficiency, less energy is used for heating and cooling, which lowers operating emissions. According to sustainability documents, mass timber's energy efficiency contribution not only helps to lower daily energy consumption but also supports global efforts to decrease emissions of greenhouse gases (Abed et al., 2022; Damtoft et al., 2008).

End-of-Life Sustainability: Mass timber's environmental credentials are also affected by its end-of-life phase. Mass timber's sustainability profile is boosted by being able to be reused or recycled at the end of its useful life. This gives it an edge over materials like concrete, which might not have simple or eco-friendly end-of-life choices. Mass timber's overall environmental impact is further decreased by its recyclability, which makes it a desirable option for sustainable building methods (Abed et al., 2022).

Lifecycle Comparative Analysis: Research has demonstrated that mass timber structures have a lower overall carbon footprint than steel and concrete buildings. This is because wood could sequester carbon and has lower operational and embodied emissions. These characteristics highlight mass timber's potential as a practical, environmentally friendly building material that can greatly lessen the environmental impact of the construction sector (Abed et al., 2022).

Increasing the use of mass timber in building projects could contribute to achieving sustainability goals set forth in international climate efforts, such as those covered in the "Sustainable Development and Climate Change Initiatives" paper. Because of its proven benefits in reducing greenhouse gas emissions at every step of a structure's life, from construction to disposal, mass wood is an essential part of future sustainable building practices (Damtoft et al., 2008).

**Sustainability Sourcing**

Assuring that wood production is renewable and preserves ecological balance, mass timber comes from forests that are sustainably managed, meaning that harvesting does not outpace growth. This approach lessens the overall environmental impact while promoting the protection of biodiversity. Furthermore, compared to more conventional materials like steel and concrete, mass timber production uses less energy, which greatly reduces greenhouse gas emissions during the manufacturing process (Abed et al., 2022).

Similar sustainable sourcing initiatives are also seen in the cement and concrete industries. To save resources and cut emissions, it uses alternative raw materials and methods to lower the amount of clinker in cement (Damtoft et al., 2008). Like mass timber, these techniques support a circular economy by extending the lifecycle of wood products while decreasing waste via recycling and reuse (Abed et al., 2022). Together, these documents show a move toward sustainable building methods using a variety of materials. By prioritizing energy efficiency, materials that are recyclable, and renewable resources, the construction sector is establishing a benchmark for sustainability. This strategy shows the industry's dedication to environmental stewardship by reducing climate change while backing global sustainable development goals (Damtoft et al., 2008).

**Life Cycle Analysis**

A thorough examination of several life cycle assessments (LCAs) devoted to mass timber construction (MTC) reveals that mass timber has major advantages over conventional building materials like steel and concrete and offers deep insights into its environmental impacts at different stages of a building's lifecycle (Duan et al., 2022). It points out that mass lumber has substantially less embodied greenhouse gas emissions, about 42.68% lower than those of reinforced concrete (RC) alternatives, but exhibits a higher average embodied energy by roughly 23%. This implies that mass lumber has a far lower lifetime greenhouse gas output, even if its production phase uses a lot of energy. The study emphasizes the significance of considering both life cycle primary energy (LCPE) and global warming potential (GWP), since mass timber typically has lower values in these areas than steel and RC structures, indicating a lessened environmental impact, especially about global warming.

However, Liang et al. (2021) compare the environmental performance of a concrete construction with that of a mass timber building in the Pacific Northwestern United States. Using a 60-year research period, life cycle assessment (LCA) encompasses the extraction and processing of raw materials, manufacture, transportation, construction, operation, maintenance, and end-of-life stages. With a reported 12% decrease in GHG emissions, this study emphasizes that mass timber construction uses less energy and has less embodied carbon than concrete buildings. Furthermore, more than 90% of greenhouse gas emissions are recorded during the building's operational phase, underscoring the importance of mass timber's inherent insulating qualities in improving energy efficiency and lowering operating emissions.

Throughout their lives, mass timber structures provide substantial environmental benefits, particularly in terms of lower energy consumption and greenhouse gas emissions, while having a larger initial embodied energy. These results strengthen the case for mass wood as an environmentally friendly building material that may help lower greenhouse gas emissions worldwide and promote sustainable building techniques. Mass timber's life cycle assessment positions it as a major player in the transition to more ecologically friendly building technologies by demonstrating not only its feasibility as a building material but also its potential to meet global sustainability goals (Duan et al., 2022; Liang et al., 2021).

**Project Management Practices in Construction Industry**

**Importance of Project management**

According to (FT & R, 2000) project managers are essential to the construction sector because they make sure that projects are finished on schedule, within budget, and to quality standards. They also must manage resources, organize intricate stakeholder engagements, and reduce risks. Although the goal of building project management (BPM) is to increase efficiency, research indicates that its actual use, especially in the USA, has not always produced the anticipated gains. Some projects have shown only modest progress in time and cost management, and some have even had detrimental effects on quality. Since it unifies different components for a successful project delivery and satisfies increasing client needs for superior performance, project management is still essential. As construction evolves, continuous improvement in management practices is essential to address both technical and interpersonal challenges, ensuring projects meet their objectives efficiently (Ferrada et al., 2016).

**Complexity and Scale**

The complexity of contemporary construction projects is rising due to a number of variables, including project scale, scope, originality, and the incorporation of cutting-edge technologies and sustainability considerations. Since decisions made at one step frequently affect other phases, this complexity necessitates the efficient management of several stakeholders, deadlines, and risks (Mavi & Standing, 2018). Delays and cost overruns are also commonly caused by inadequate planning, scheduling, and resource allocation expertise as well as poor knowledge management. Project managers need to be technically proficient and have good leadership abilities to manage stakeholder expectations, align organizational resources, and reduce risks. For high-quality projects to be delivered successfully and efficiently, experiential learning and ongoing knowledge transfer are essential (Yap et al., 2016).

**Evolution of Practices**

In the construction sector, project management has changed dramatically, shifting from manual, old procedures to more sophisticated strategies that make use of contemporary tools and technologies. The way projects are planned, tracked, and carried out has been completely transformed by the combination of cloud computing, mobile devices, and information and communication technologies (ICT). These developments solve issues with scalability and stakeholder coordination by enabling real-time data access, enhanced knowledge sharing, and smooth team collaboration (Ferrada et al., 2016). Construction managers can improve decision-making by managing project information more effectively with the use of tools like cloud computing and mobile shared workspaces. Research indicates that many project managers are not making the most of these technologies, despite their obvious advantages, which may have an impact on project results. Improving overall project efficiency and success requires the proper use of these contemporary technologies, continual training, and customization to project-specific requirements (Al-Hajj & Zraunig, 2018).

**Key Focus Area**

A variety of important topics are the focus of effective project management in the construction sector, which guarantees the successful completion of projects. To avoid scope creep while retaining the project's alignment with its goals, scope management is crucial for establishing and managing the project's boundaries. Since delays can have a major impact on the success of a project, time management is essential to ensure that all operations are finished on time. Keeping the project within budget, dealing with cost overruns, and making sure resources are distributed effectively are all part of cost management. Maintaining quality control ensures that the project's output fulfils the necessary demands, resulting in client satisfaction and long-term worth. To minimize project disruptions, risk management entails early risk identification and the implementation of mitigation or elimination techniques. Finally, communication is essential for enabling transparent and productive interactions amongst all stakeholders and guaranteeing that everyone is on the same page and informed at every stage of the project (Al-Hajj & Zraunig, 2018).

**Project Management in Mass Timber Projects**

Mass timber construction introduces a transformative shift in project management, demanding new workflows that emphasize early collaboration, detailed coordination, and integrated technology. As a prefabricated system, mass timber construction relies on accurate design documents, efficient logistics, and early stakeholder engagement. Unlike traditional steel or concrete systems where modifications can be made during the construction phase, mass timber projects require decisions to be finalized well in advance to avoid costly errors during manufacturing and erection.

The use of Cross-Laminated Timber (CLT), for example, necessitates meticulous planning due to its prefabricated nature and limited flexibility for on-site changes. As highlighted in a San Francisco-based mass timber case study, the pre-drilled CLT panels meant that the MEP systems had to be precisely coordinated during the design phase to prevent clashes, as any errors would lead to delays and rework in manufacturing and logistics (Krueger, 2023).

From the project management perspective, mass timber projects require intensive involvement from general contractors (GCs), fabricators, MEP subcontractors, and specialty consultants throughout the design phase. The U.S. Mass Timber Construction Manual underscores this necessity by emphasizing early engagement from the GC/CM, installers, and specialty contractors, which is critical to resolving design and fabrication issues before construction begins(WoodWorks, 2021).

Additionally, the integration of tools like Building Information Modeling (BIM) plays a significant role in managing mass timber projects. BIM enables early clash detection, design review, and improved coordination across disciplines, supporting the shift of decision-making to earlier phases of the project life cycle (WoodWorks, 2021)

One key takeaway from the case study was the recognition that installing mass timber components required unique logistical planning. Project teams had to consider crane schedules, material delivery constraints, and site storage due to the size and precision of timber panels. The general contractor even repurposed a concrete crew for installation due to their experience with cranes and wood, which proved more effective than using traditional steel erection teams

**Effective Project Management in the Preconstruction Phase of Mass Timber Projects**

Because mass timber projects rely heavily on off-site prefabrication, the preconstruction stage is essential to laying the groundwork for the project's success. To avoid delays, efficient project management guarantees that the designs are completed, and materials are acquired in advance (Krueger, 2023). Project managers are essential in ensuring that prefabricated pieces are supplied in the right order by monitoring their manufacture and transportation using sophisticated scheduling tools and real-time tracking systems. Errors in this stage might result in delays and expensive rework (Lehman & Kremer, 2023).

During preconstruction, cooperation and coordination are crucial. The complexity of mass timber projects requires early and close collaboration between stakeholders, including designers, manufacturers, contractors, and subcontractors (Jörg et al., 2017). Early in the design process, project managers need to make sure that all systems mechanical, electrical, and plumbing MEP are incorporated into prefabricated components. Since post-fabrication modifications are sometimes challenging and costly, this degree of collaboration is required to prevent mistakes or costly alterations later (Krueger, 2023).

Project managers must carefully manage schedule and logistics in addition to coordination. The exact timing of material delivery and crane availability for on-site assembly are key components of prefabrication. Delays in this stage may lead to more disturbances. In order to guarantee the prompt delivery and installation of prefabricated components, effective project management entails thorough planning in addition to handling logistical issues including securing storage and transportation routes (Krueger, 2023; Lehman & Kremer, 2023).

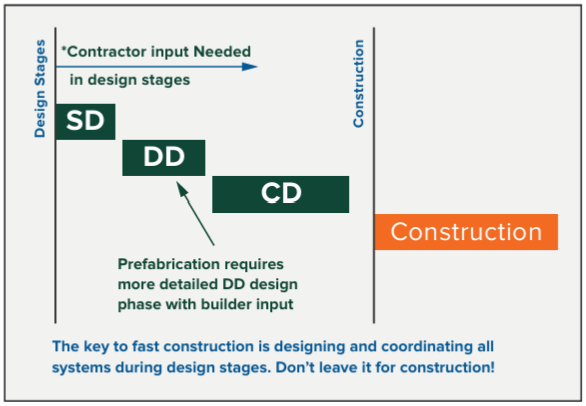


*Figure 8 Builder input and engagement is essential during (Woodworks 2021)*

Furthermore, during preconstruction, risk management and quality control are essential duties. Since some workers may not be experienced with mass wood tools and processes, project managers must supervise the quality of prefabricated components and make sure that safety procedures are followed. This emphasis on quality and safety helps to avoid on-site mishaps and guarantees the project's seamless completion (Jörg et al., 2017; Krueger, 2023).

All things considered, it is impossible to overestimate the significance of project management during the preconstruction stage of mass timber projects. It guarantees that systems are integrated, designs are completed, logistics are controlled, and risks are reduced, all of which contribute to a more effective and fruitful project conclusion.

**Barriers and Research Need**

The lengthy pre-construction periods that are sometimes necessary for mass timber construction projects are mostly caused by the absence of an organized project management methodology. Mass timber requires special procedures including pre-fabrication, precision cutting, and intricate coordination between several stakeholders, including mechanical, electrical, plumbing (MEP), and fire protection teams, in contrast to conventional materials like steel and concrete. The pre-construction stage is frequently extended to guarantee correct alignment between design and execution because of the inexperience with these procedures. Teams must invest more time in organizing activities, checking designs for conflicts, and handling logistics in the absence of a conventional project management framework that considers the unique requirements of mass timber. This inefficiency emphasizes the necessity for customized

project management techniques that can expedite the pre-construction stage, cutting down on delays and raising mass timber projects' overall effectiveness (Krueger, 2023).
Due to the lack of a formal project management framework tailored to the unique characteristics of mass timber construction, the upfront planning and design phase presents significant challenges. Since changes after fabrication are both difficult and costly, the design of large-scale timber projects must be fully completed prior to manufacturing. This front-loaded process requires close coordination among all project teams - including architects, engineers, and contractors - particularly when integrating mechanical and electrical systems.

However, teams lack precise guidance for handling this critical phase since there is no standardized project management model that takes these complications into account. This gap in current industry practices arises because most existing project management models are designed for traditional materials like steel and concrete and are not well-suited to the unique requirements of mass timber projects. Addressing this gap could lead to better cost control, more efficient processes, and reduced project delays. It would also offer a clearer path for future research and contribute to the development of industry best practices. (Ryan E et al., 2018).

## Research Methods, Objectives and Steps

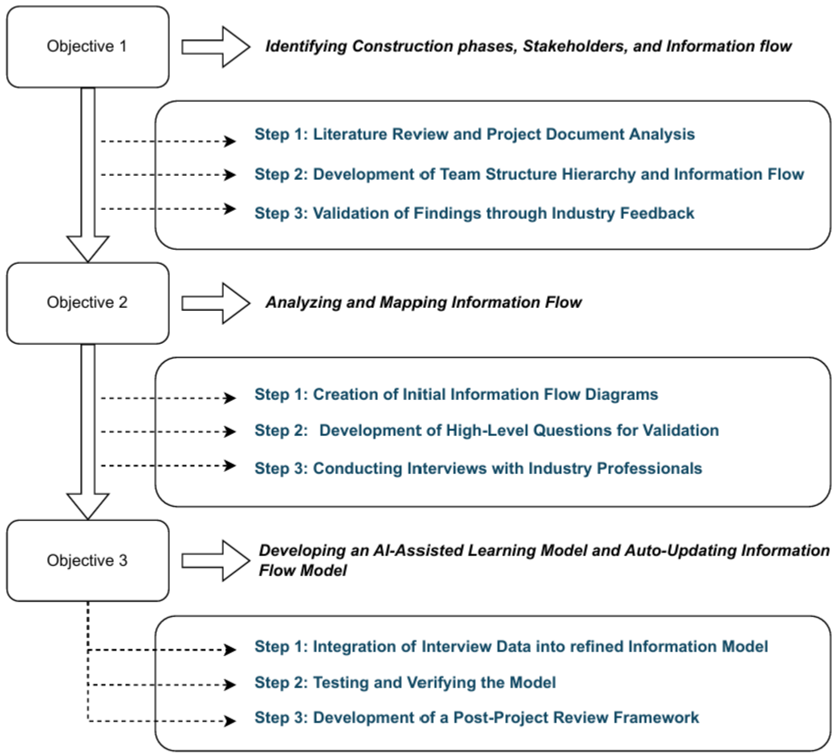


*Figure 9 Research Methods, Objectives and Steps*

This study integrates both theoretical (a priori) and empirical (a posteriori) approaches to investigate project management practices and information flow within mass timber construction (MTC) projects. The study aims to improve understanding of the organizational structure, roles of stakeholders, and the flow of information during the preconstruction phase. The methodology is structured around three primary objectives:

Objective 1: Identifying Key Phases and Stakeholders and interactions between stakeholders

The first objective focuses on identifying the critical phases of mass timber projects, preliminary design, design development, preconstruction, and construction; and mapping the roles and responsibilities of key stakeholders such as project owners, architects, engineers, and contractors. A comprehensive literature review and analysis of real project documents will form the foundation. Initial models, such as team structures and communication pathways, are created from these insights to define the organizational hierarchy and interaction between stakeholders.

Objective 2: Analyzing and Mapping Information Flow

The second objective aims to develop detailed information flow diagrams and provide a structured framework that map the exchange of information between teams across different phases of mass timber projects. Initial flowcharts are developed based on models, focusing on key communication and decision-making points between stakeholders. These models are validated through semi-structured interviews with industry professionals. A total of 8 industry professionals will be selected in this process. Feedback from interviews helps refine the diagrams, identifying bottlenecks in communication and inefficiencies in the flow of information, particularly in critical phases like preconstruction.

Objective 3: Developing an AI-Assisted Model and Auto-Updating Information Flow Model

The main goal of Objective 3 is to create an AI-assisted model for mass timber construction project management. This AI model aims to provide real-time project management recommendations and updates. The process involves initially training the AI model with validated industry data to ensure it accurately reflects actual conditions. The model is then regularly updated with new information gathered from ongoing projects to maintain its relevance and accuracy. This continuous update mechanism allows the AI to adapt to changing project dynamics and provide the most current advice, ensuring that the workflow remains efficient and responsive to new data and trends. With further development, this model has the potential to evolve into a more robust and efficient tool that supports broader applications across various types of mass timber construction projects.

**Research Scope and Limitations**

The research investigates project management practices specifically during the preconstruction phase of mass timber construction projects.

The scope of the research includes:

Key Stakeholders and Phases: Identifying the key phases of mass timber projects, including the Preliminary Design Development, and Preconstruction phases. The research focuses on the roles and responsibilities of key stakeholders such as architects, structural engineers, contractors, construction managers, and project owners.

Flow of Information: Analyzing and mapping the flow of information between various teams in these phases. This includes examining how information is exchanged, what communication methods are used and the timing of critical information exchanges.

Verification through Industry Input: The research employs both literature review and empirical verification. The theoretical frameworks for team structure and information flow are developed based on project documents and industry literature, then validated through interviews with industry professionals experienced in mass timber projects.

Technology Integration: The study explores the use of advanced project management tools such as BIM and software solutions that help streamline communication and reduce project delays. This includes assessing which tools are most effective for supporting mass timber projects, particularly during the preconstruction phase.

Sustainability and Innovation Focus: The research also touches on sustainability benefits of mass timber construction, such as carbon sequestration, and how innovative project management practices can accelerate its adoption in the U.S. construction industry.

Limitations:

Limited Stakeholder Experience: Mass timber construction is a relatively new approach in the U.S., and as such, many stakeholders (including architects, contractors, and project managers) may have limited experience working with this material. The findings of this research rely on insights from industry professionals, but the level of experience with mass timber projects varies significantly. This variation may influence the depth and quality of feedback during empirical verification, potentially limiting the accuracy of the conclusions drawn from stakeholder interviews.

Scope of Phases: The research focuses solely on the preconstruction phase of mass timber projects, which includes activities such as design development, cost estimation, and procurement planning. While this phase is critical for the success of mass timber projects, the research does not explore the challenges and management practices in the construction and post-construction phases. Therefore, findings and recommendations are specific to the preconstruction phase and may not address issues that arise during actual on-site construction or after project completion.

Limited Data Availability: Due to the relatively small number of mass timber projects completed in the U.S., there is a limited pool of data available for analysis. This restricts the ability to draw broad, generalizable conclusions across the industry. The research is based on a select few case studies and projects, which may not fully represent the diversity of practices or challenges encountered in the broader mass timber construction landscape.

**Anticipated Outcomes**

The anticipated outcomes of this research include a comprehensive identification of the key phases and stakeholders involved in mass timber construction, providing a structured framework to improve project management efficiency. Additionally, the research will produce enhanced information flow models that address communication bottlenecks, facilitating smoother coordination across project teams. A tailored project management framework specific to mass timber will be developed, optimizing processes such as prefabrication and early-stage coordination to reduce delays and costs.

Furthermore, the research explores the integration of Artificial Intelligence (AI) in mass timber construction, particularly in automating decision-making, enhancing real-time project monitoring, and improving data-driven insights for better stakeholder collaboration. The AI-assisted model developed in this study aims to refine information exchange processes, predict potential project inefficiencies, and provide continuous learning through post-project review analysis. Ultimately, the research will provide actionable recommendations for industry's best practices, contributing to more standardized and effective management approaches while laying the foundation for AI-driven innovations in mass timber construction.

## CHAPTER 2: LITERATURE REVIEW / BACKGROUND

### Introduction

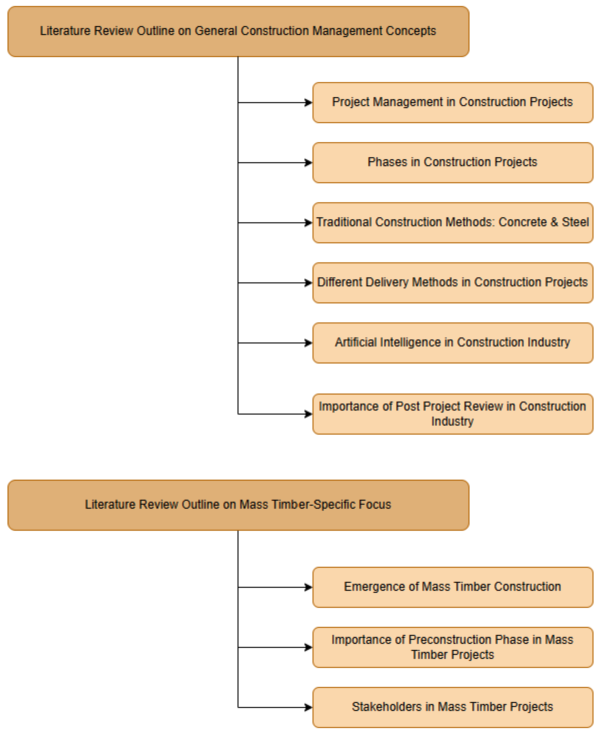


*Figure 10 Literature Review Outline*

Theories of project management have developed to address many facets of successfully managing projects. The Project Management Body of Knowledge (PMBOK), Agile, and Lean approaches are some of the most well-known. With a focus on knowledge areas like integration, scope, time, money, quality, human resources, communication, risk, procurement, and stakeholder management, PMBOK offers a thorough framework that incorporates best practices, procedures, and standards necessary for project management (Winch & Kesley, 2005) (Chin & Hamid, 2015).

To ensure clear organization, planning, and control throughout the lifecycle of construction projects, it focuses on the following areas: business justification, specified organization structure, product-based planning strategy, and project division into manageable stages. The agile technique, which emphasizes iterative development and cross-functional team cooperation, is tailored for projects that demand quick adjustments and ongoing improvement. It is intended for initiatives that demand flexibility and reactivity. In order to streamline construction procedures and enhance project results, project management seeks to maximize value by reducing waste, prioritizing efficiency, streamlining procedures, and getting rid of non-value-added operations (Sui Pheng & Leong, 2001).

Effectively managing scope, time, money, quality, human resources, communications, risk, procurement, and stakeholders are all fundamental components of project management. To guarantee that all necessary work is done, scope management entails defining and regulating what is included and omitted from the project (Chin & Hamid, 2015). Using techniques like Gantt charts, the Critical Path Method (CPM), and the Program Evaluation and Review Technique (PERT), time management focuses on organizing, scheduling, and regulating project operations to guarantee timely completion.

(Sui Pheng & Leong, 2001). To keep the project within the authorized budget, cost management entails cost forecasting, variance analysis, and cost estimation, budgeting, and control (Winch & Kesley, 2005). Through quality planning, assurance, and control procedures, quality management guarantees that the project's outputs fulfill the necessary standards and meet the needs of stakeholders. Project team organization, management, and leadership are all part of human resource management, which also includes performance management, team development, and resource planning. To involve stakeholders and ensure project success, effective communications management concentrates on creating, gathering, disseminating, and preserving project information. Through planning, evaluation, and mitigation techniques, risk management entails recognizing, evaluating, and reacting to project hazards. Procurement management deals with acquiring goods and services from external sources, ensuring timely and cost-effective acquisition of necessary resources. Stakeholder management makes ensuring that all project participants are located, that their requirements and expectations are recognized, and that the right engagement techniques are used to win their support and reduce opposition (Chin & Hamid, 2015) (Sui Pheng & Leong, 2001).

**Project Management in Construction Projects**

Building information modeling (BIM) is a digital depiction of the construction process that uses data interchange to enhance cooperation and communication. Design visualization, quantity take-offs, clash detection, scheduling, cost calculation, and facility management are among its applications. By offering precise and comprehensive digital models, BIM improves planning, design, construction, and operation. Better project visualization decreased errors and rework, increased stakeholder communication, and increased documentation correctness are some advantages of BIM. By integrating BIM tool functions with current work processes, BIM implementation encourages a technology pull strategy (Hartmann et al., 2012). Through early key participant involvement and objective alignment through shared risks and benefits, Integrated Project Delivery (IPD) is a collaborative method that aims to improve project outcomes. A cohesive project team will result in better project quality, shorter construction times, and significant cost savings. This is achieved through the fundamental IPD principles of mutual trust and respect, collaborative decision-making, and early stakeholder engagement. IPD has drawbacks, such as the need for organizational culture changes, complicated contractual arrangements, and the need for cutting-edge technology to facilitate collaboration, despite its advantages, which include increased productivity, improved leadership, and creative solutions (Kahvandi et al., 2019). Other obstacles include initial implementation expenses, legal and insurance concerns, and resistance to change. Nonetheless, successful IPD implementation has shown statistically significant improvements in project performance, making it a valuable approach in the construction industry(El Asmar et al., 2013) (Kent & Gerber, 2010).

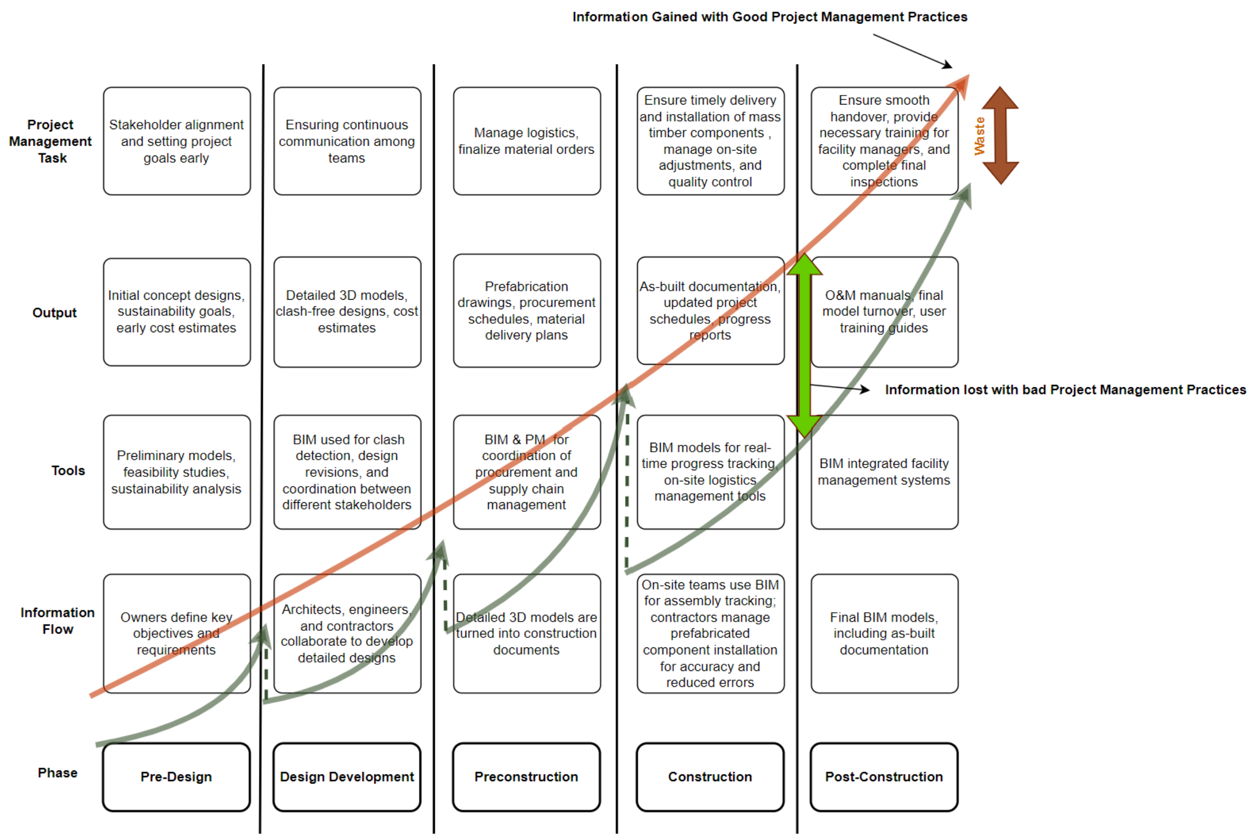


*Figure 11 Importance of Project Management (Adapted from Fallahi, 2017)*

Significant obstacles that affect project success are faced by construction management, such as staffing shortages in less desirable locales and problems with documentation. Timelines are sometimes delayed by logistical difficulties in remote areas. Small contractors frequently lack the resources necessary for efficient scheduling and quality control, which increases the risk of errors and rework. Furthermore, local regulatory concerns and communication limitations increase complexity, necessitating strong approaches like utilizing technology, strengthening employee training, and fostering better communication to overcome these obstacles (Tran et al., 2015).

Since it establishes the foundation for most construction decisions, the construction planning stage is essential to the project development and delivery phase. A defined foundation for time and financial plans is established by effective project planning, which guarantees successful project completion. Even though this stage is crucial, many construction companies, especially small-to-medium-sized ones, handle it haphazardly, which results in inefficiencies and higher expenses (Syal et al., 1992).

Since this field is still largely unknown, management is especially crucial in large-scale timber construction projects. Mass wood construction presents special problems that can be addressed by effective management techniques, improving project outcomes and encouraging broader use of this sustainable building technique.

Industry Practices: To measure project performance and progress objectively, industry methods like Earned Value Management (EVM) are crucial. EVM allows for the early detection of deviations from the project plan by integrating scope, time, and cost metrics to provide correct project status and anticipate future performance (Sui Pheng & Leong, 2001). Software solutions for construction management are also essential for resource allocation, budgeting, and scheduling. Better decision-making and project control result from these technologies' ability to track data in real-time, improve stakeholder cooperation, and offer extensive reporting features. Techniques like stakeholder involvement and risk management are also essential. Early risk identification and mitigation strategy development are essential components of effective risk management, and stakeholder engagement guarantees that all parties are in agreement with the aims and objectives of the project (Abdullah et al., 2016).

**Phases in Construction Projects**

Initiation, planning, execution, monitoring and control, and closure are the five main stages that make up a construction project's lifecycle. Every stage is essential to a project's effective conclusion. The project's goals and objectives are established at the commencement phase, and its viability is evaluated. Creating comprehensive project plans that address scope, time, money, quality, human resources, communication, risk, procurement, and stakeholder management is part of the planning phase.

(Sui Pheng & Leong, 2001). Project plans are carried out and resources are distributed among different tasks during the execution phase. To follow project progress and guarantee conformity with the project plan, monitoring and control are carried out concurrently with execution. During the closure phase, all project activities must be completed, all paperwork must be completed, and the project deliverables must be formally accepted (Abdullah et al., 2016).

**Traditional Construction Methods: Concrete & Steel**

A composite material with exceptional compressive strength is used in concrete construction, frequently reinforced with steel rebar. Techniques include prefabrication, which offers quality control and speedier construction but necessitates transportation coordination, and cast-in-place, which is perfect for foundations but labor-intensive and weather-dependent. Although concrete is strong, fireproof, and adaptable, it requires a lengthy curing period (Hamzeh et al., 2017). An iron-carbon alloy used in steel construction is renowned for its strong tensile strength and recyclable nature. High-rise steel framing is strong and quick to manufacture, but it must be fireproofed (Rashid et al., 2016). Although prefabrication guarantees accuracy and saves time, there are transportation issues. Although steel is robust, pliable, and environmentally friendly, it is also more expensive initially and prone to corrosion (Heravi et al., 2021).

**Different Delivery Methods in Construction Projects**

It is crucial to consider how various project delivery techniques can affect project outcomes when choosing one for building projects, especially those employing cutting-edge materials like mass wood. Every delivery method, including Design-Bid-Build (DBB), Construction Manager at Risk (CMAR), and Design-Build (DB), has advantages and disadvantages of its own. Early contractor engagement and the application of integrated methodologies are especially crucial in the context of mass timber building to manage the intricacies of prefabrication and assembly and guarantee the project's success. (Khwaja and others, 2022).

Due to its sequential procedure and exclusion of contractor participation during the design phase, the traditional DBB technique, despite its widespread use, frequently results in lengthier project timelines. The CMAR and DB techniques, on the other hand, provide more integrated approaches that enable early contractor involvement, which helps reduce risks and enhance results, particularly in complicated projects like mass timber projects. While DB speeds up project schedules by combining design and construction into a single contract, CMAR makes it easier for the owner, designer, and contractor to collaborate. When selecting a delivery method, the text also emphasizes how crucial it is to take owner preferences, project-specific considerations, goals, and risks into account.

Techniques to lessen subjectivity in the selection process are reviewed, including multi-attribute analysis, the Analytical Hierarchy Process (AHP), and Case-Based Reasoning (CBR). Early contractor participation through CMAR or DB is advised for mass timber projects to handle difficulties such prefabrication and material sourcing, with a significant emphasis on the institutional background and experience of the owner. Design-Build (DB) and Integrated Project Delivery (IPD) are especially well-suited for mass timber projects, according to (WoodWorks, 2021). Because precise coordination during prefabrication and assembly is necessary for the efficient execution of mass wood building, these methods promote early collaboration between design and construction teams. While IPD unites all parties under a single contract, encouraging shared risk and cooperative decision-making, DB streamlines project durations by combining design and construction into a single contract. On the other hand, the conventional DBB approach might have trouble coordinating the particulars of bulk timber, which could lead to delays. For bulk timber projects, DB and IPD are therefore advised as the best delivery methods since they provide improved integration, risk management, and project success in general.

**Emergence of Mass Timber Construction**

Between 2015 and 2020, the development and broad use of Cross-Laminated Timber (CLT) significantly accelerated the growth of mass timber building in the US. After being first demonstrated in Europe, CLT evolved into a revolutionary product that made it possible for it to be included in the 2015 International Building Code (IBC), which was a turning point for the American building sector. The 2021 IBC, which allows the use of CLT in structures up to 18 stories, further accelerated this change by increasing the potential for mass timber in sustainable and urban construction. Mass timber's increasing popularity is also qualified to its aesthetic appeal and environmental advantages, such as a reduced carbon footprint. As these materials have become more accepted, a surge in research, testing, and code development has supported their broader application in the U.S. market, positioning mass timber as a viable and attractive alternative to traditional construction methods(WoodWorks, 2021).

Key Drivers: Environmental advantages, sustainability, improvements in wood technology, and modifications to building codes are the main drivers of the rebirth of mass timber construction. Design teams and developers are drawn to mass timber because of its low carbon footprint and visual attractiveness. High-rise timber buildings are made possible by technological developments such as CLT, which are reinforced by the 2021 IBC's provisions for mass timber structures up to 18 stories (WoodWorks, 2021). Even though mass timber is becoming more and more popular as building material, obstacles including inexperienced contractors, difficult regulations, supply chain limitations, and construction management techniques frequently make it difficult to complete these projects successfully. These subjects represent important research gaps in the field of mass timber building, and I hope to fill them as part of my study.

**Importance of Preconstruction Phases in Mass Timber Project**

For mass timber projects to be successful overall, the preconstruction stage is essential. Mass timber projects, in contrast to traditional construction, mostly rely on off-site prefabrication of components like glue-laminated timber and cross-laminated timber. As a result, careful planning, coordination, and risk management are crucial right from the beginning. The general contractors, mass timber suppliers, fabricators, and subcontractors such as the mechanical, electrical, and plumbing teams are among the important players that project managers need to be involved early in this phase. Before building starts, constructability evaluations and design problems can be resolved by early and ongoing collaboration, which lowers the possibility of expensive rework or delays (WoodWorks, 2021).

Because mass timber components are prefabricated and must fit together perfectly during installation, careful planning is crucial. Mass wood projects are less flexible for last-minute changes than traditional construction methods, which allow for on-site modifications. This necessitates that project managers prioritize tasks including material selection, shop drawings, and construction sequencing (WoodWorks, 2021).

Project managers are responsible for ensuring that material delivery and staging are properly coordinated in terms of timing and logistics. Project managers must consider crane availability, storage, and on-site access because mass timber components are huge and need special handling. The project timeline may be severely impacted by material delivery delays or inappropriate handling, thus meticulous logistics planning is essential. Mass wood projects also present a unique cost management challenge because, in contrast to traditional approaches, additional costs are incurred during the preconstruction period. Even though thorough design, prefabrication, and logistics have greater upfront costs, the project as a whole frequently benefits from quicker installation timeframes and lower labor costs throughout the building phase(WoodWorks, 2021).

During the preconstruction stage, risk management is also a top concern, especially in relation to insurance, quality assurance, and fire safety. Certain fire safety precautions, such as applying fire-resistant sealants and coatings at crucial intersections, are necessary for mass timber constructions. Since mass wood is still a relatively new material in many jurisdictions and not all code inspectors may be familiar with it, project managers must make sure that local building standards and insurance needs are followed. To prevent delays in the permission process, it is essential to address these concerns as soon as possible by interacting with regulatory agencies (WoodWorks, 2021).

In conclusion, most of the planning, coordinating, and decision-making for mass timber projects takes place during the preconstruction phase, and effective management of this phase is critical to the project's successful completion. This stage necessitates the use of cutting-edge technology like BIM, early stakeholder participation, meticulous risk management, and rigorous cost and schedule planning. Project managers can make use of mass timber's environmental advantages while ensuring quicker construction, lower costs, and better results by front-loading these tasks.

### Stakeholders in Mass Timber Projects

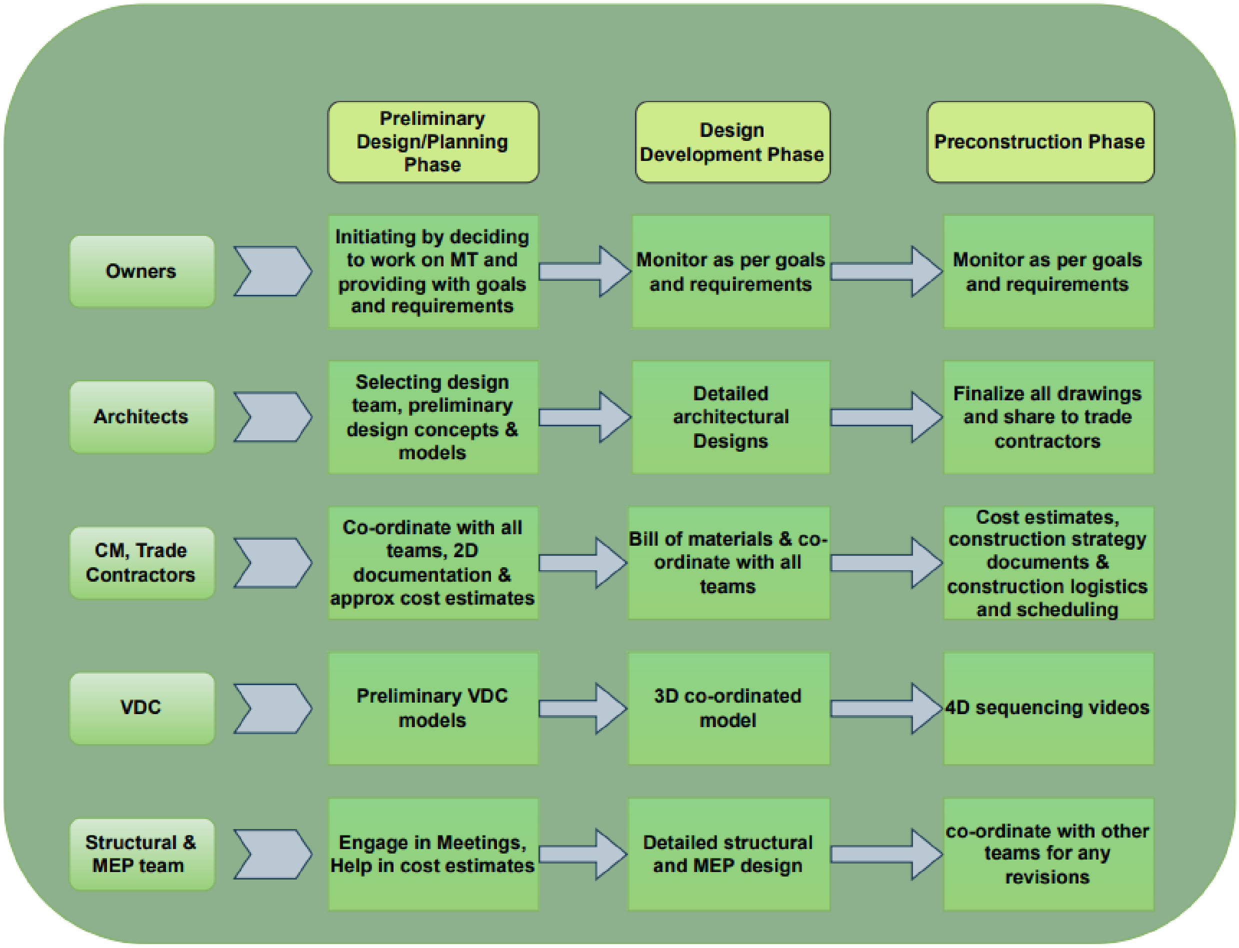


*Figure 12 Stakeholder Roles and Information Flow in Early Phases of Mass Timber Projects (Adapted from Fallahi, 2017)*

The success of building projects depends on efficient channels of communication and decision-making procedures, which include organized communication tactics and cooperative decision-making among several stakeholders. Transparency and real-time information sharing are improved by stakeholder interaction through frequent meetings, updates, and cooperative digital platforms like Building Information Modeling (BIM). This promotes a cooperative atmosphere by guaranteeing that all stakeholders are aware, on the same page, and capable of handling expectations and issues (Jing et al.). At various project stages, decision-making authority is shared among project managers, architects, engineers, contractors, and owners. Architects and engineers make early technical decisions, while project managers and contractors concentrate on execution and resource allocation. Major milestones and budgetary issues are monitored by owners and financial stakeholders. To ensure that the project's objectives, schedules, and budgets are fulfilled, effective decision-making necessitates teamwork, transparent communication, and the use of technology to negotiate logistical, financial, and technological challenges (Wuni & Shen, 2020). Conflicting interests, breakdowns, and coordination problems are some of the difficulties that stakeholder management in construction projects faces and can result in arguments and delays. Large, complicated projects with numerous stakeholders and insufficient participation make these issues worse and leave demands and concerns unsatisfied. Effective project management practices, clear communication plans, conflict resolution mechanisms, and active stakeholder engagement are crucial to addressing these challenges and ensuring project success(Mashali et al., 2023).

Since information flow is crucial in mass wood initiatives, it is imperative to involve most stakeholders early on. It is crucial to get the specifications correct the first time because any changes can be very difficult and expensive because supplies are ordered from far away. For this reason, to guarantee thorough planning and efficient mass wood project execution, I am incorporating all relevant parties in my investigation.


*Figure13 Document Flow and Stakeholder Responsibilities Across Construction Project Phases (Adapted from Fallahi, 2017)*

**Artificial Intelligence in Construction Industry**

Through the use of technologies like machine learning, natural language processing (NLP), predictive analytics, and robots, artificial intelligence (AI) is transforming construction management by increasing automation, streamlining processes, and strengthening decision-making (Pan & Zhang, 2021; Regona et al., 2022). By combining cutting-edge technologies like Building Information Modeling (BIM), digital twins, and optimization algorithms, AI adoption in Construction Engineering and Management (CEM) tackles industry issues like inefficiencies, low labor productivity, and safety hazards. The application of Generative Pre-trained Transformer (GPT)-based models, which facilitate real-time decision-making, automate document analysis, and enhance stakeholder communication, is one of the most important developments in artificial intelligence (Abioye et al., 2021; Bilal et al., 2016). These models process vast amounts of construction data, extract valuable insights from technical reports, and enhance knowledge-sharing across teams, leading to more efficient project planning and execution.

The integration of AI with BIM and Virtual Design and Construction (VDC) further enhances construction processes by enabling automated clash detection, intelligent scheduling, and real-time project monitoring, significantly reducing costs and improving efficiency(Pan & Zhang, 2021). AI-driven predictive analytics allow project teams to foresee risks, anticipate failures, and implement mitigation strategies proactively, minimizing disruptions in project execution(Regona et al., 2022). Additionally, AI plays a crucial role in post-project learning by analyzing completed projects, identifying inefficiencies, and refining best practices for future projects, ensuring continuous improvement in construction methodologies. GPT-based AI models, in particular, contribute to this process by synthesizing stakeholder feedback, tracking recurring project challenges, and generating data-driven recommendations that enhance decision-making and process optimization.

Despite its transformative potential, AI adoption in construction still faces challenges such as data fragmentation, a lack of standardization, and high implementation costs, which hinder widespread deployment(Abioye et al., 2021). Addressing these barriers requires collaborative efforts across the industry, development of standardized data-sharing protocols, and continued research into AI applications tailored for complex construction environments. As AI technologies continue to evolve, GPT-based systems are expected to play a key role in driving digital transformation in construction, enhancing project efficiency, fostering innovation, and integrating AI-driven models into standard project management workflows(Bilal et al., 2016; Pan & Zhang, 2021; Regona et al., 2022).

By automating processes, boosting risk mitigation, and fostering better stakeholder communication, artificial intelligence (AI) is revolutionizing construction project management. Applications of artificial intelligence (AI), such as machine learning, predictive analytics, and natural language processing (NLP), are being utilized more and more to improve supply chain management, project scheduling, and post-project assessments. Machine learning models, such as regression analysis, classification, and clustering algorithms, analyzing historical project data to predict potential risks, optimize resource allocation, and prevent delays, enabling more proactive decision-making and cost control. Additionally, AI-driven predictive analytics enhances project planning by forecasting performance trends based on historical data, ensuring that potential bottlenecks are addressed before they impact schedules(Pan & Zhang, 2021). The adoption of Generative Pre-trained Transformers (GPT) in construction management further streamlines decision-making by extracting insights from vast volumes of textual project data, automating knowledge retrieval, and generating data-driven recommendations for project teams. AI-driven systems also support stakeholder collaboration by synthesizing construction reports, identifying discrepancies, and ensuring alignment between design and execution phases. AI-powered scheduling tools incorporate predictive models to anticipate material lead times, mitigate supply chain disruptions, and improve logistics planning, ultimately increasing efficiency and reducing construction delays. Furthermore, in post-project evaluations, AI models facilitate continuous learning by capturing feedback, tracking recurring challenges, and refining best practices for future construction projects, ensuring that industry-wide improvements are sustained over time(Uhm et al., 2025). While AI adoption in construction is advancing rapidly, challenges such as data fragmentation, lack of standardization, and integration complexities remain significant barriers to full-scale implementation, necessitating further research and industry-wide collaboration to maximize AI’s potential benefits in construction project management.

Artificial Intelligence (AI) has been increasingly utilized in post-project reviews and continuous learning within the construction industry, enabling automated lessons learned and structured project performance assessments. AI-driven models analyze historical project data to detect inefficiencies, identify recurring issues, and suggest actionable improvements, fostering an iterative learning process for future projects. Applications of AI, such as natural language processing and machine learning (NLP), extract insights from vast amounts of construction documentation, providing a structured approach to performance evaluation and knowledge retention(Abioye et al., 2021). Research highlights AI’s role in pattern detection, predictive analytics, and risk assessment, enabling proactive strategies to mitigate delays and cost overruns. Specifically, Generative Pre-trained Transformer (GPT) models enhance post-project assessments by synthesizing data from various reports, streamlining information management, and generating context-driven recommendations for continuous process optimization. AI-driven models utilize retrieval-augmented generation (RAG) techniques, ensuring that recommendations are based on real-world project data and expert-validated knowledge(Rane, 2023). The GPT-based model developed for mass timber construction (MTC) integrates past project feedback, dynamically refining outputs, and improving accuracy in identifying project risks and scheduling inefficiencies. This adaptive approach allows construction teams to optimize decision-making, minimize recurring issues, and implement industry best practices in the industry, ensuring that past experiences contribute to enhanced project execution over time.

**Importance of Post Project Review in Construction Industry**

Post-project reviews play a crucial role in construction by systematically capturing lessons learned, improving project execution, and refining industry’s best practices. These reviews help organizations analyze cost management, scheduling efficiency, and stakeholder collaboration, ensuring that knowledge is retained and applied to future projects. Effective PPRs identify both successes and failures, mitigating the risk of repeating mistakes and enhancing communication across project phases(Alzahrani & Emsley, 2013). However,(Carrillo, 2005) states challenges such as time constraints and lack of standardized procedures often hinder their implementation, leading to lost institutional knowledge. Research highlights that digital tool, including AI-driven models and knowledge management systems, can streamline post-project evaluations by automating data collection, generating actionable insights, and providing predictive recommendations for future project improvements. By institutionalizing structured PPR frameworks, construction firms can foster continuous learning, improve decision-making, and enhance overall project efficiency.

Artificial Intelligence (AI) is transforming post-project review analysis in construction by automating data collection, analyzing historical trends, and providing predictive insights to improve future project planning. Machine Learning (ML) and Natural Language Processing (NLP) enable AI-driven models to detect patterns in project execution, assess risk factors, and optimize performance based on historical data(Omotayo et al.). AI-powered frameworks enhance decision-making by extracting insights from large volumes of project documentation, identifying inefficiencies, and offering data-driven recommendations for continuous improvement. Additionally, as per(Loforte Ribeiro & Leitão Tomásio Ferreira, 2010), AI-driven post-project evaluations facilitate knowledge retention by integrating lessons learned into structured models, improving scheduling accuracy, supply chain efficiency, and overall stakeholder collaboration. These advancements ensure that construction firms benefit from an evolving knowledge base that refines best practices and mitigates recurring project risks.

# CHAPTER 3: RESEARCH METHODOLOGY

## Introduction

This chapter outlines the research methodology employed to achieve the objectives of this study, focusing on the project management practices and information flow within mass timber construction (MTC) projects. The methodology is designed to ensure a comprehensive understanding by integrating both a priori (theoretical) and a posteriori (empirical) approach. This dual approach allows research to benefit from existing knowledge while also validating the frameworks against real-world practices.

A Priori Approach: The a priori reasoning in this research involves the development of frameworks derived from existing knowledge found in academic literature, industry reports, and project documents. This approach allows the researcher to establish initial hypotheses, models, and structures before engaging with real-world data. By starting with a priori reasoning, the research capitalizes well-established theories and concepts, ensuring that the initial models are rooted in solid academic and professional foundations.

Theoretical Frameworks: In the context of this study, a priori reasoning is used to develop frameworks that outline the phases of mass timber construction, the roles and responsibilities of key stakeholders, and the anticipated flow of information between them. These frameworks are based on comprehensive literature reviews and analysis of project documents, providing a structured understanding of mass timber projects.

Initial Models: The models, such as team structure hierarchies and information flow diagrams, are constructed using a priori knowledge. These serve as the starting point for further refinement, ensuring the research is grounded in established practices while allowing room for modification based on empirical findings.

A Posteriori Approach: The a posteriori reasoning involves empirical verification of the frameworks through data collected from industry professionals. This stage of the research provides an opportunity to test the accuracy, relevance, and practicality of the initial models by comparing them with real-world practices in mass timber projects. The incorporation of a posteriori knowledge ensures that the research is not only theoretical but also applicable to current industry practices.

Empirical Verification: In this study, a posteriori reasoning is crucial for validating the models developed in the a priori phase. Semi-structured interviews with industry professionals allow the researcher to gather real-world insights on team structures, information flow, and project management practices in mass timber projects.

Refinement of Models: The feedback gathered from these interviews is used to refine the initial models, ensuring that they reflect actual challenges, communication processes, and decision-making procedures encountered in practice. This empirical verification makes the final models more robust and adaptable to real-world applications.

Integration of A Priori and A Posteriori Approaches

The integration of a priori and a posteriori approach ensures that the research is comprehensive, combining theoretical rigor with practical relevance. This dual approach not only allows the researcher to build on existing knowledge but also enables adjustments based on the realities of the industry. The use of both approaches ensures that the research is grounded in theory while remaining responsive to the needs and practices of professionals in mass timber construction.

The methodology is structured around three main objectives, each addressing a different aspect of the research:

Objective 1 focuses on identifying the key phases, stakeholders, and information flow in mass timber construction projects through both literature review (a priori) and verification from industry experts (a posteriori).

Objective 2 involves analyzing and mapping the flow of information across the various phases of a mass timber project. Initial flow diagrams are developed using theoretical knowledge (a priori), followed by interviews with industry professionals to verify and refine these models (a posteriori).

Objective 3 focuses on developing an AI-assisted model and a post-project review framework to enhance decision-making and continuous learning in mass timber construction. This objective involves integrating empirical data (a posteriori) from industry interviews to train and refine the AI model while leveraging structured methodologies (a priori) to create an auto-updating information flow system. The AI model is designed to provide real-time insights, optimize stakeholder coordination, and support post-project evaluations, ensuring continuous improvement in MTC project execution.

The methodology is designed to ensure that the frameworks are not developed in isolation but are thoroughly validated through real-world insights. This combination of approaches ensures the outcomes are both academically rigorous and practically applicable in the construction management of mass timber projects.

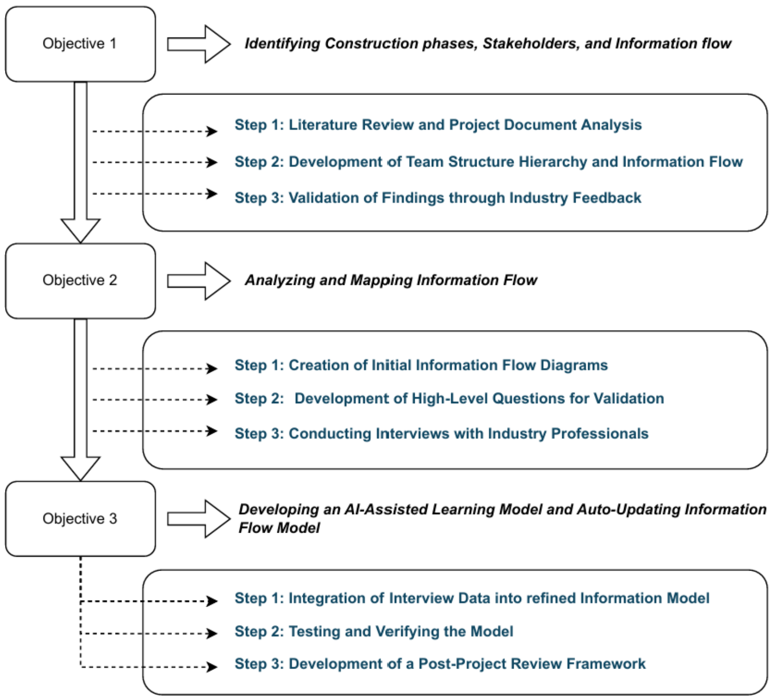


*Figure 14 Research Methods, Objectives and Steps*

**Objective 1: Identifying Construction Phases, Stakeholders, and Information Flow**

This objective focuses on identifying the key phases of mass timber construction projects, the roles and responsibilities of stakeholders involved, and how information is exchanged between them. This forms the foundation of the study, providing a framework that will be validated with real-world insights in later steps. The process begins with a priori (theoretical) research through literature reviews and project document analysis and culminates in a posteriori verification through industry feedback.

Step 1: Literature Review and Project Document Analysis (A Priori)

Purpose: The purpose of this step is to gather knowledge on the phases of mass timber construction projects, the roles and responsibilities of stakeholders, and the flow of information between them.

Procedure:

Comprehensive Literature Review:

The first step of the research involves a comprehensive review of academic literature, industry reports, and case studies on mass timber construction, which is essential for establishing a strong foundation. This review will focus on understanding the structure of mass timber construction projects, the key phases involved preliminary design, design development, preconstruction, execution, and post-construction and the evolving roles of stakeholders like architects, engineers, contractors, and owners. By reviewing manuals, technical publications, academic papers, and industry reports, It is possible to gather insights into standardized procedures, trends, and innovative practices in mass timber projects. This foundational knowledge will guide the development of models in the later stages of my research, to be validated through empirical data.

Project Document Collection and Analysis:

In addition to reviewing existing literature, Collection of real-world project documents is done to gain practical insights into mass timber construction. These documents may include contracts, communication protocols, project schedules, RFI's from actual mass timber projects. Analyzing these documents will provide concrete examples of how teams are structured and how information flows between them in real projects. This analysis is critical for bridging the gap between knowledge and practical application, ensuring that this research is not only grounded in academic frameworks but also reflective of real-world industry practices. By examining these documents, the actual processes and methods used in mass timber projects can be identified, helping to refine the models developed from the literature review.

Identification of Key Phases:

Through the literature review and document analysis, the key phases of mass timber projects will be identified and defined, which include the Preliminary Design Phase, involving initial planning and concept development, and the Design Development Phase, where the detailed design is refined, and coordination between the design and engineering teams occurs, the Preconstruction Phase, focusing on material procurement, cost estimation, and finalizing strategies, and the Construction Phase, where on-site construction, prefabrication, and assembly take place. Each phase involves distinct stakeholders, with specific roles and communication needs essential for seamless project execution.

Step 2: Development of Team Structure Hierarchy and Initial Information Flow (A Priori)

Purpose: The purpose of this step is to create a framework that outlines the team structures and flow of information throughout the various phases of a mass timber project, based on the findings from the literature review and project document analysis.

Procedure:

Mapping Construction Phases to Teams:

For each phase identified in Step 1, the relevant teams involved will be mapped out, including architects, engineers, general contractors, owners, and project managers. The primary goal of this step is to thoroughly understand who the key players are in each phase and how they contribute to the project. Each phase of a mass timber project, whether design, preconstruction, execution, or post-construction will likely involve a different combination of stakeholders, each carrying specific roles and responsibilities. Mapping these roles across the different phases ensures that the flow of responsibilities is clearly outlined and that all relevant stakeholders are accounted for throughout the project lifecycle.

Identifying Information Exchange Points:

At each phase of the project, identifying the key points where information is exchanged between teams is crucial. The types of information exchanged, such as design details, procurement orders, schedules, and other critical data, along with the methods used to transfer this information, will be documented. These methods may include BIM systems for 3D modeling and coordination, email for formal communications, or project management platforms that provide a centralized space for sharing updates, timelines, and files. Understanding how information flows between teams will be crucial for analyzing whether the current practices are efficient or if there are bottlenecks and delays that could be improved.

Developing the Team Structure Hierarchy:

Once the roles, responsibilities, and information exchange points are clearly defined, a team structure hierarchy will be developed to visually represent the relationships between the different teams involved in the project. This hierarchy will serve as a blueprint to illustrate the reporting lines, communication pathways, and the overall interaction between teams throughout the project's lifecycle. By mapping out how teams such as architects, engineers, contractors, and owners communicate and collaborate at different stages, the hierarchy will make it easier to understand the flow of responsibility. Additionally, this structure will emphasize the interdependencies between teams and phases, which are crucial for identifying potential risks This visualization will be essential for identifying critical points where improvements in communication and coordination could significantly enhance project efficiency.

Generating Preliminary Flowcharts:

In this step, the flow of information within and between project phases will be visualized by creating flowcharts. These flowcharts will depict how information moves from one team to another and across different phases of the project, providing a clear and structured representation of communication pathways. The overall goal is to create a visual representation of how information flows in a mass timber project, grounded in both theoretical insights from the literature and real-world practices observed through document analysis. This will offer a practical tool for understanding and improving the efficiency of information exchange in future projects.

Step 3: Verification of Findings (A Posteriori)

Purpose: The purpose of this step is to validate the team structure hierarchy and information flow diagrams developed in Step 2 using real-world insights gathered from experienced industry professionals.

Procedure:

Identification of Industry Professionals:

A group of industry professionals with extensive experience working on mass timber projects will be selected. This group will likely include project managers, architects, engineers, and contractors who have been actively involved in the various phases of mass timber construction. It is crucial to ensure that the professionals chosen for verification have a comprehensive understanding of both team structures and information flow in mass timber projects, as their expertise will provide critical insights into the practical application of the models. Their feedback will be essential for refining and validating the developed frameworks, ensuring that they align with the real-world practices and challenges of mass timber construction. 8 to 10 members will be selected to ensure diverse perspectives and experiences are represented during the verification process.

Preparation for Verification Criteria:

A set of criteria or key points will be developed to guide the verification process, ensuring that the models accurately reflect real-world practices. These criteria will focus on several important aspects, such as the accuracy of team roles and responsibilities and the effectiveness of the information flow mechanisms. For instance, one key criterion will assess whether the team structure hierarchy accurately represents the real-world roles and relationships between stakeholders, such as architects, engineers, and contractors. Another criterion will evaluate whether the information flow captured in the models aligns with typical communication patterns observed in mass timber projects. Additionally, the criteria will include checks to determine whether any important stakeholders or critical information exchange points have been omitted, ensuring that the models comprehensively cover all aspects of team interactions and communication pathways. These criteria will provide a structured approach to validating the models with industry professionals, ensuring that the findings are both accurate and practically applicable.

Engagement for Feedback:

The frameworks, including the team structure hierarchy and information flowcharts, will be shared with the selected industry professionals to gather their feedback. This will be done through discussions or semi-structured interviews to seek insights on the accuracy and practicality of these frameworks. The aim is to encourage these professionals to highlight any discrepancies between the models and the real-world practices they have experienced in mass timber projects.

Following this, the refinement phase will commence, utilizing the feedback gathered during verification to adjust the team structure hierarchy and information flow diagrams. The goal is to ensure that the models better reflect actual practices in the field.

**Objective 2: Analyzing and Mapping Information Flow**

The purpose of Objective 2 is to analyze and map the flow of information between teams across different phases of mass timber projects. This step involves creating initial information flow diagrams based on models and refining them through verification with industry experts. By examining how information is exchanged and processed, this objective aims to identify bottlenecks, improve efficiency, and ensure that project stakeholders are well-coordinated.

Step 1: Creation of Initial Information Flow Diagrams (A Priori)

Purpose:

The goal of this step is to map out the ideal flow of information between teams during the different phases of the project, based on models and previous research findings.

Procedure:

Utilizing the Validated Team Structure:

To begin, the validated team structure hierarchy developed in Objective 1 will be used as a foundation for creating information flow models. This hierarchy defines the roles and responsibilities of various stakeholders and serves as the basis for understanding how information should flow between these teams across different project phases.

Identification of Information Exchange Points:

Key points where information is exchanged between teams within each phase will then be identified. The objective here is to map these critical exchange points to understand how decisions are made and how data flows through the project. The assessment will focus on identifying which teams initiate information transfers, who receives them, and the types of information that are shared.

Drafting Flowcharts:

Once the key exchange points are identified, detailed flowcharts will be developed to visualize the flow of information. These flowcharts will show how data moves within each phase and between phases. These flowcharts will not only illustrate communication pathways but also highlight how teams coordinate and collaborate at each stage of the project.

Incorporation of Theoretical Insights:

To ensure the accuracy of the flowcharts and their alignment with best practices, knowledge from the literature review and project document analysis conducted in Objective 1 will be integrated. This will help ensure that the flowcharts reflect standard industry practices in mass timber construction, capturing both the ideal flow of information and identifying potential gaps or inefficiencies in current systems. This framework will serve as a baseline for the next steps, where it will be further validated and refined through real-world insights.

Step 2: Development of High-Level Questions in the Selected Critical Phase (A Priori)

Purpose:

The purpose of this step is to develop high-level questions that will help validate the flow of information within a critical phase of the project. These questions are designed to target specific aspects of information flow, such as accuracy, effectiveness, and challenges.

Procedure:

Selection of Critical Phase:

The process will begin by reviewing the flowcharts developed in Step 1 to select a critical phase of the project for detailed analysis. The preconstruction phase is often chosen due to its complexity, as it requires extensive coordination between design, procurement, and construction teams. This phase is particularly crucial because delays or errors in information flow during preconstruction can have significant downstream impacts on material delivery and construction timelines, especially in mass timber projects.

Question Development:

After selecting the critical phase, high-level questions will be developed to focus on several key areas of information flow, such as:

Information Accuracy: Questions will explore the precision and reliability of the information exchanged between teams.

- Team Interactions: Assessing the effectiveness of communication and collaboration between different teams.
- Decision-Making: The questions will prove how the flow of information impacts critical project decisions.

- Challenges: I will examine common bottlenecks or issues in the flow of information, such as delays in data sharing, miscommunications, or unclear responsibilities that cause project delays or inefficiencies.

Assessment of Tools and Systems:

In addition to questions about information flow, questions will also be included regarding the effectiveness of tools and systems, such as BIM, project management platforms, and communication protocols, used to manage information exchange. This will help assess how well these tools facilitate collaboration and identify any limitations or areas for improvement. The goal is to understand whether the existing systems support smooth communication or if there are technical or procedural barriers that hinder information transfer.

Step 3: Conducting Interviews with Industry Professionals (A Posteriori)

Purpose:

The purpose of this step is to gather empirical data through interviews with industry professionals who have experience in mass timber projects, to validate and refine the information flow models created in the previous steps.

Procedure:

Selection of Interview Participants:

A total of 8 to 10 industry professionals will be selected for the interviews, including those involved in the verification process with direct experience working within the selected critical phase of mass timber projects will first be identified. This group may include project managers, architects, engineers, and contractors. Their experience in handling real-world information flow challenges will provide valuable insights into the accuracy and effectiveness of the models.

Interview Preparation:

An interview guide will be prepared based on the high-level questions developed in Step 2 to effectively guide the interviews. This guide will ensure that the discussions remain focused on the key areas of information flow, tools, and systems within the selected critical phase. This guide will focus the discussions on specific areas such as information accuracy, team interactions, and tools used for managing data exchanges.

The guide will ensure that key topics are covered while allowing for flexibility in exploring other relevant issues raised by the interviewees.

Conducting Semi-Structured Interviews:

The interviews will be conducted in a semi-structured format, which allows for both structured questions and open-ended discussions. This format is ideal for gathering qualitative data, as it gives interviewees the opportunity to provide detailed explanations of their experiences. During the interviews, participants will be asked to share examples of how information is managed, the communication challenges they face, and their views on what works best in mass timber projects. This will provide valuable insights into practical experiences and help identify areas for improvement.

Data Collection:

During the interviews, insights into various aspects of information management will be documented, including:

- Current information management practices: How do teams currently exchange information? What systems are used, and are they effective?
- Challenges and bottlenecks: What communication barriers or bottlenecks do teams encounter? How do these challenges impact project timelines or decision-making?
- Best practices and effective tools: What practices or tools have proven effective in managing information flow? Are there specific systems or protocols that have helped streamline communication between teams?

Refinement of Flow Diagrams:

Based on the feedback and data collected during the interviews, the flowcharts and information models developed in Step 1 will be refined. This refinement process will involve updating the models to reflect real-world practices and addressing any issues or gaps identified during the interviews. For example, if interviewees highlight common bottlenecks or communication issues, the flow diagrams will be adjusted to accurately represent these challenges.

**Objective 3: Developing an AI-Assisted Auto Updating Model**

Objective 3 is centered on the integration of AI-driven automation to enhance project management practices within the mass timber construction industry. The primary aim is to enable real time learning and continuous workflow improvements across the project lifecycle, leveraging advanced artificial intelligence technologies. A critical aspect of this objective is to assess whether AI technology can be effectively utilized in the mass timber construction context, evaluating its impact on refining project management processes, enhancing decision-making capabilities, and improving overall project outcomes.

Step 1: Integration of Interview Data into Refined Information Model

Purpose:

The purpose of this step is to incorporate empirical data from industry interviews into the Generative Pre-Trained Transformer (GPT) model developed in previous objectives. This ensures that the model accurately represents real-world practices, addressing the challenges and complexities encountered in mass timber construction project management.

Procedure:

Data Analysis:

The data collected from industry interviews was analyzed to identify recurring themes, challenges, and patterns related to project management and information flow in MTC projects. Common issues such as bottlenecks in communication, role ambiguity, and coordination inefficiencies were categorized to refine the model.

Model Refinement:

The initial information flow diagrams and team structure hierarchy developed in previous objectives were adjusted based on industry feedback and refinements included modifying stakeholder roles, updating communication pathways, and incorporating additional decision-making steps to reflect real world practices.

Creating GPT Model:

The refined model was compared with the industry’s best practices and existing project documentation to ensure consistency and applicability. The model was structured to provide a clear representation of how information flows across different phases of MTC projects, ensuring alignment with industry standards.

Step 2: Testing and Verifying the Model

Purpose:

This step focuses on testing the refined information model in simulated industry scenarios and verifying its accuracy and practicality with industry professionals. The goal is to ensure that the model effectively represents real world information flow and project management structures in MTC projects.

Procedure:

Simulation-Based Testing:

The GPT model was tested using simulated mass timber construction scenarios that mirrored real world project conditions.

AI-Assisted Validation:

The AI model was tested with structured questions developed from output from interviews to evaluate whether it provided accurate and contextually relevant responses. The model was restricted to using only the provided dataset to ensure that all outputs were derived from validated industry knowledge rather than external sources.

Step 3: Development of a Post-Project Review Framework

Purpose:

The final step involves developing a structured post project review framework that ensures continuous learning and improvement in MTC project management. This framework integrates AI driven automation to track recurring challenges and refine the information flow model over time.

Procedure:

Designing the Review System:

A structured post project review framework was designed to systematically collect feedback from completed mass timber projects. The framework enables project stakeholders to document lessons learned, communication gaps, and process inefficiencies.

Auto-Updating Information Flow Model:

Structured template is created to update the information flow model based on feedback from completed projects. This ensures that the model remains dynamic, adapting to evolving industry trends and challenges.

AI Powered Trend Analysis:

The AI model was programmed to analyze trends from post project data, identifying recurring issues and areas for improvement. Key insights generated by AI were structured into actionable recommendations for refining project management strategies in future MTC projects.

# CHAPTER 4: RESULTS AND DATA ANALYSIS

## Introduction

The successful management of mass timber construction projects relies heavily on effective communication and the seamless flow of information across various phases and stakeholders. Each phase - Preliminary Design, Design Development, and Preconstruction requires specific documentation, approvals, and coordinated actions among stakeholders, including Project Owners, Architects, Engineers, Construction Managers, and VDC (Virtual Design and Construction) Integrators. The unique characteristics of mass timber projects, such as the emphasis on prefabrication, early-stage BIM modeling, and regulatory compliance, introduce additional layers of complexity to this information flow.

In previous chapters, a framework was established for understanding the flow of information across these project phases, informed by an extensive literature review and initial document analysis. Through this process, detailed information flow diagrams were created for each phase, mapping out the key interactions, feedback loops, and documents exchanged among stakeholders. These diagrams serve as a model for stakeholder interactions in mass timber projects, highlighting the roles and responsibilities of each team member and the documents critical for project continuity.

This chapter focuses on the verification and validation of these information flow diagrams. By engaging with industry professionals who have firsthand experience in mass timber projects, the aim is to ensure that the developed models accurately reflect real world practices. The verification process not only validates the existing diagrams but also provides insights into potential gaps or enhancements, thereby refining the framework to better match practical requirements.

To achieve this, a combination of general and phase specific questions was developed, designed to facilitate a structured yet flexible feedback process. General questions focus on the overall accuracy and relevance of the diagrams, while phase-specific questions allow for a deeper analysis of each phase’s unique interactions. This approach ensures comprehensive validation, allowing experts to freely share their insights without being overly directed by specific queries, thus avoiding bias in the feedback process.

### Information Flow Mapping and Stakeholder Roles

This section presents a detailed mapping of information flow and stakeholder interactions across the key phases of mass timber construction projects: Preliminary Design, Design Development, and Preconstruction. Each phase involves distinct roles, document exchanges, and collaborative processes among stakeholders, including Project Owners, Architects, Engineers, Construction Managers, VDC Integrators, and Code Consultants. By outlining the responsibilities and interactions in each phase, this section highlights the critical flow of information necessary to ensure effective coordination and successful project progression. The findings draw on both theoretical models and verification feedback from industry experts, allowing for a practical view of how information flow supports project outcomes in mass timber construction.

### Preliminary Design Phase

The Preliminary Design phase is the foundational stage of mass timber projects, where the project's vision and feasibility are established. Key stakeholders, including the Project Owner, Architects, Structural Engineers, Construction Managers (or General Contractor), and VDC Integrators, play critical roles in shaping the project's direction. The Project Owner provides initial goals, budget, and high-level requirements, guiding Architects in developing preliminary design concepts. Architects collaborate closely with Structural Engineers to ensure the design meets mass timber's unique structural requirements, while Construction Managers provide constructability feedback to align the design with budget and schedule constraints. VDC Integrators contribute by creating an initial BIM model, integrating inputs from various stakeholders to support visualization, coordination, and early clash detection. The information flow in this phase relies on continuous feedback loops and document exchanges among stakeholders, ensuring that the design is both feasible and aligned with project goals. Figure 15 illustrates this information flow, highlighting the essential exchanges that establish a strong foundation for the subsequent phases.

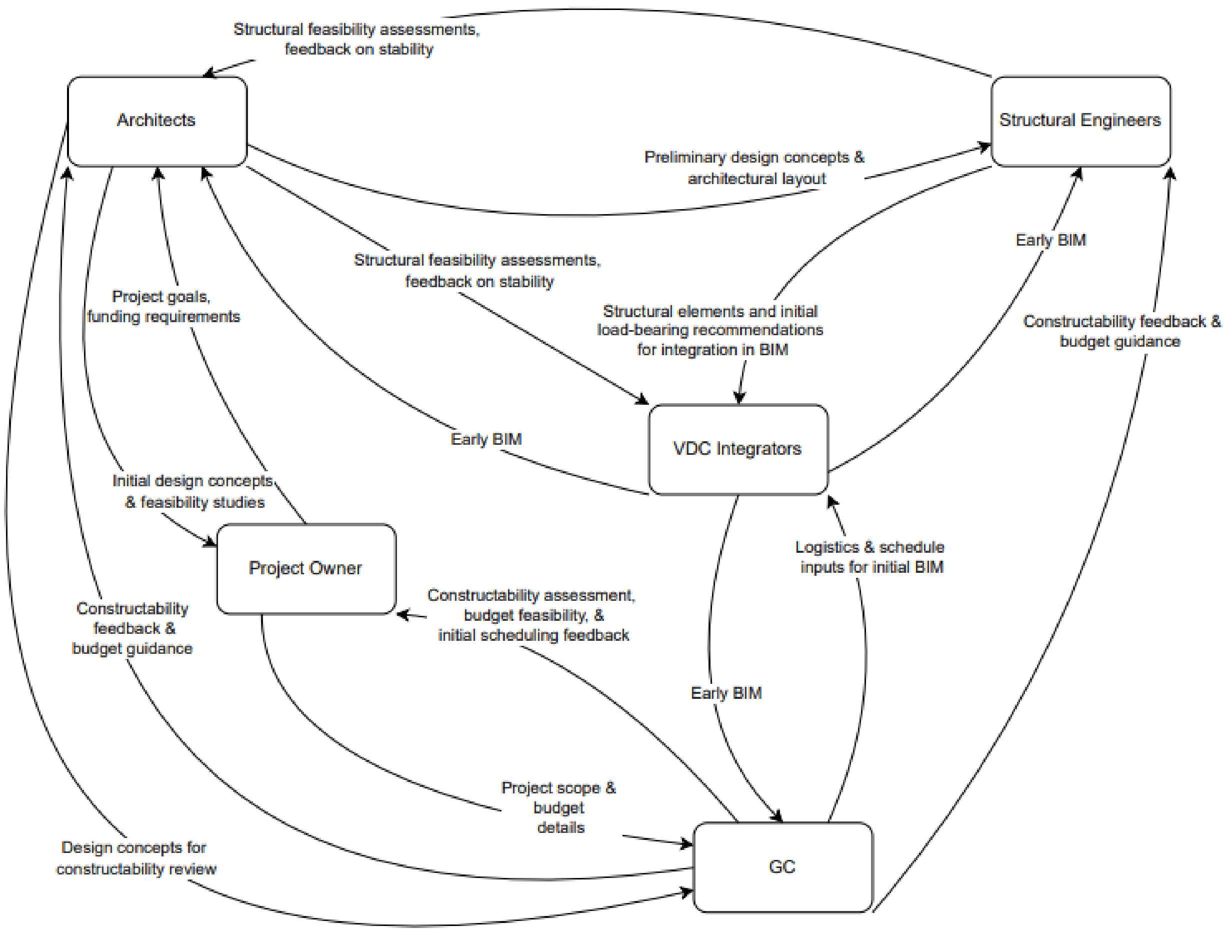


*Figure 15 Preliminary Design Phase Information Flow Diagram*

**Design Development Phase**

The Design Development phase refines the initial concepts from the Preliminary Design phase into detailed architectural, structural, and MEP (Mechanical, Electrical, and Plumbing) plans, ensuring technical feasibility, regulatory compliance, and readiness for construction. Key stakeholders, including the Project Owner, Architects, Structural Engineers, MEP Engineers, VDC Integrators, Code Consultants, and the General Contractor (GC), collaborate closely to achieve these objectives. Architects advance the design by incorporating structural and MEP requirements, while Structural Engineers work on calculations and load-bearing specifications specific to mass timber. MEP Engineers integrate HVAC, plumbing, and electrical systems within the architectural and structural design. VDC Integrators, using BIM, coordinate these elements digitally to detect potential clashes and optimize construction sequencing. The General Contractor provides constructability feedback and assesses cost and scheduling impacts to ensure the design is practical for execution. Code Consultants verify that the design complies with regulatory standards, providing feedback to ensure all requirements are met before moving to the preconstruction phase. Figure 16 illustrates the information flow in this phase, highlighting the feedback loops and document exchanges essential for seamless coordination and alignment among all disciplines.

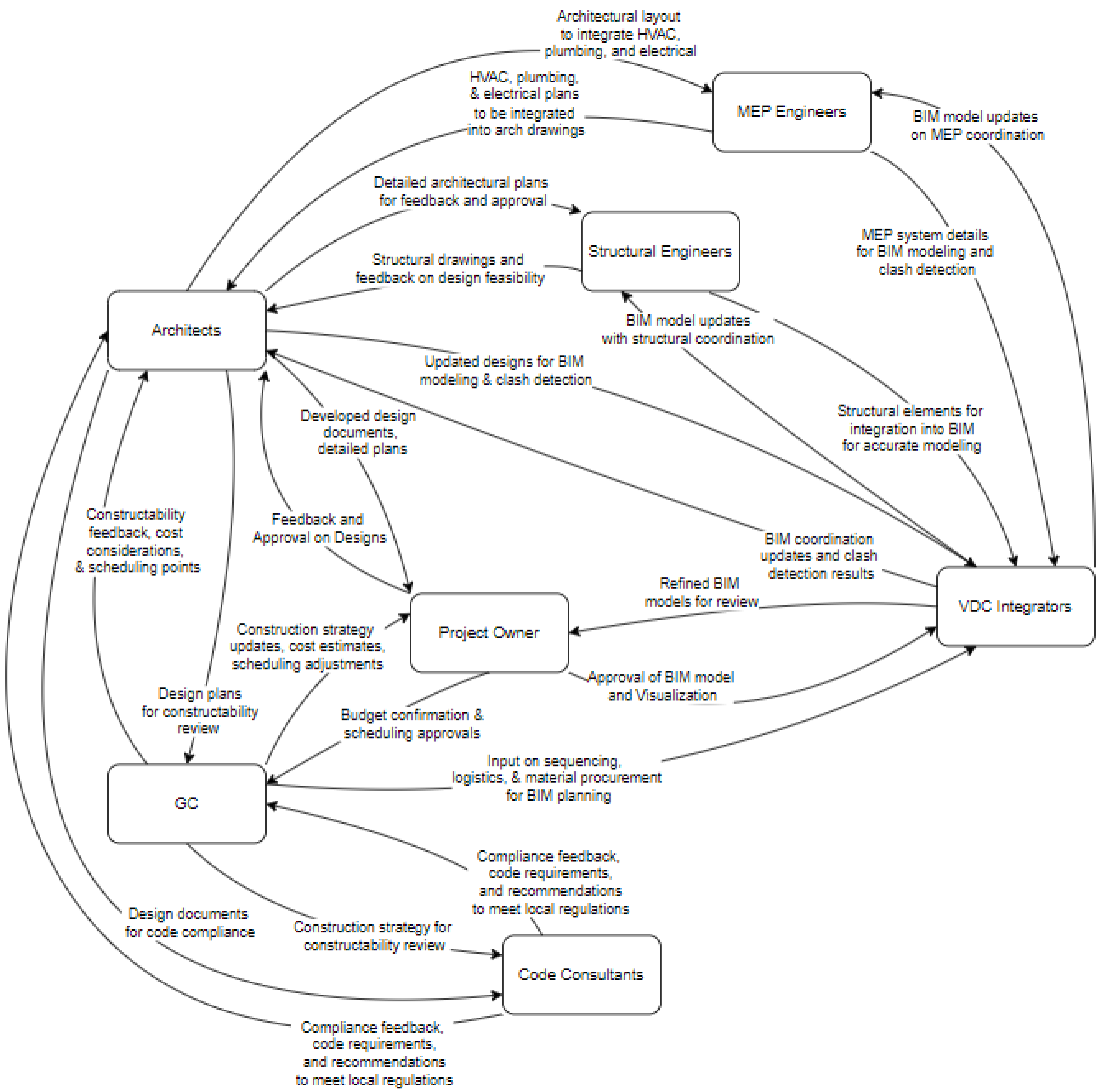


*Figure 16 Design Development Phase Information Flow Diagram*

**Preconstruction Phase**

The Preconstruction phase is focused on finalizing all project plans, logistics, and regulatory approvals to ensure readiness for the construction process. Key stakeholders involved include the Project Owner, General Contractor (GC), VDC Integrators, Subcontractors, and Building Inspectors or Code Consultants. The Project Owner provides budget updates, funding confirmations, and final approvals on the BIM model and logistics planning. The GC coordinates with the Project Owner to finalize construction strategies, sequencing, cost estimates, and schedules, while working closely with Subcontractors to clarify trade-specific requirements and installation details, ensuring materials and resources are available as needed. VDC Integrators play a crucial role in finalizing the BIM model, incorporating construction logistics and sequencing to avoid clashes and optimize workflow. Building Inspectors conduct regulatory checks, reviewing compliance documents and providing feedback on safety and regulatory requirements. Subcontractors contribute input on installation strategies, ensuring their trade-specific needs align with regulatory and logistical standards. Figure 17 illustrates the information flow in this phase, emphasizing the approvals, coordination, and regulatory feedback necessary for a smooth transition to the construction phase.

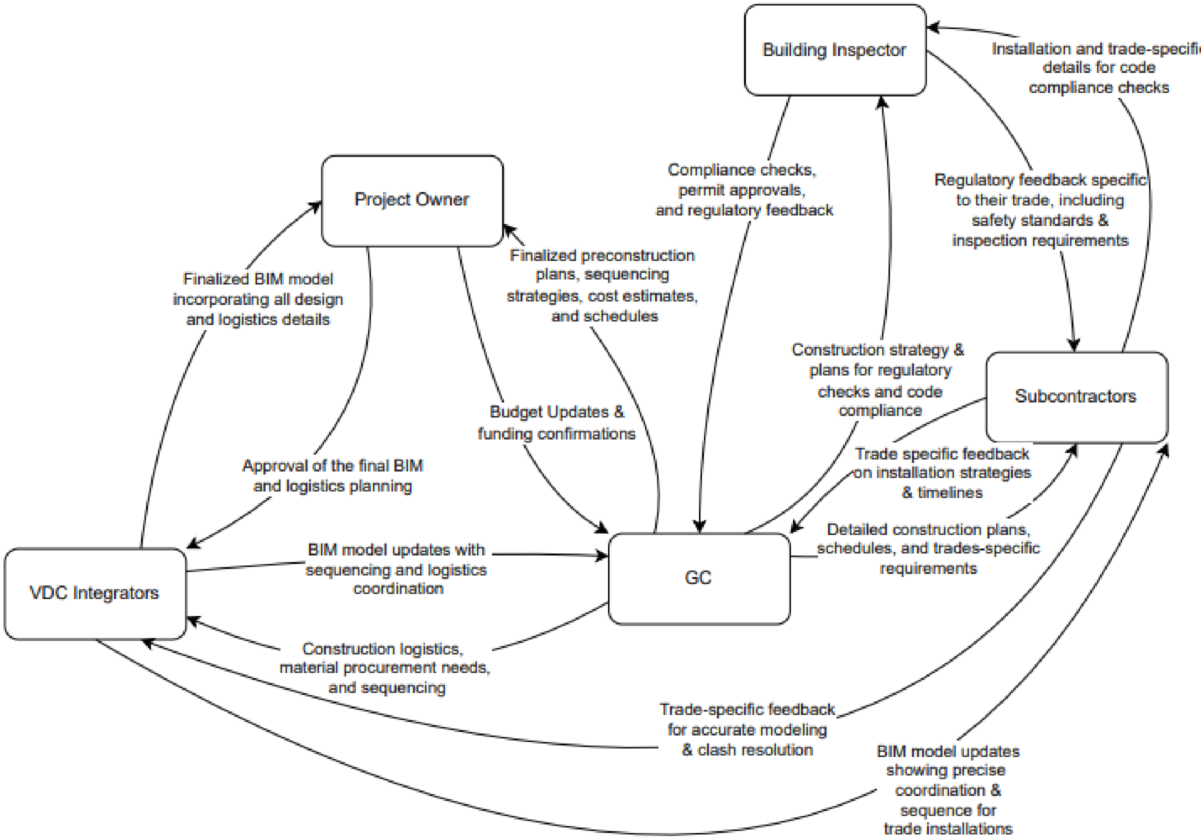


*Figure 17 Preconstruction Phase Information Flow Diagram*

Figure 18 presents a detailed mapping of information flow and stakeholder interactions across the key pre-execution phases of mass timber construction projects: Preliminary Design, Design Development, and Preconstruction. Each phase involves distinct roles, document exchanges, and collaborative processes among stakeholders, including Project Owners, Architects, Engineers, Construction Managers, VDC Integrators, and Code Consultants. Since this research is focused on project management practices before the start of the execution phase, the Construction phase is not included in this analysis. By outlining the responsibilities and interactions in each pre-execution phase, this section highlights the critical flow of information necessary to ensure effective coordination and successful project progression.

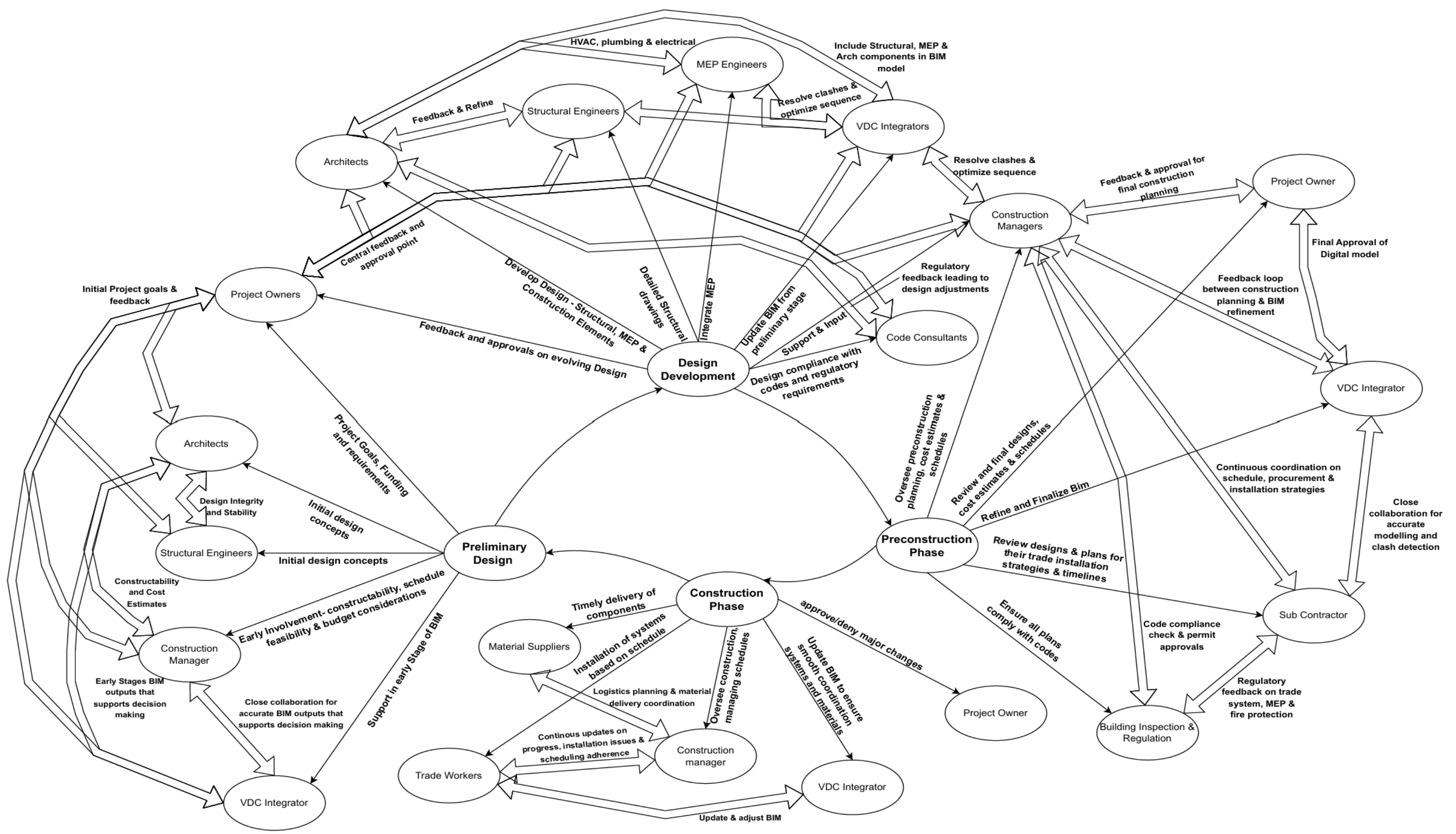


*Figure 18 Information Flow and Stakeholder Interaction*

**Sequential Information Flow Across Project Life Cycle**

Figure 19 & Figure 20 are the information flow diagrams, which illustrate the comprehensive flow of information from the start of the project through to the end of the construction phase. These diagrams depict the structured interactions and document exchanges between all key stakeholders in each phase, offering a clear representation of how communication and collaboration occur at each stage. By presenting this flow from project inception to completion, the diagrams provide a straightforward overview that industry experts can easily interpret, making it simpler to validate the effectiveness and accuracy of each interaction and document exchange.

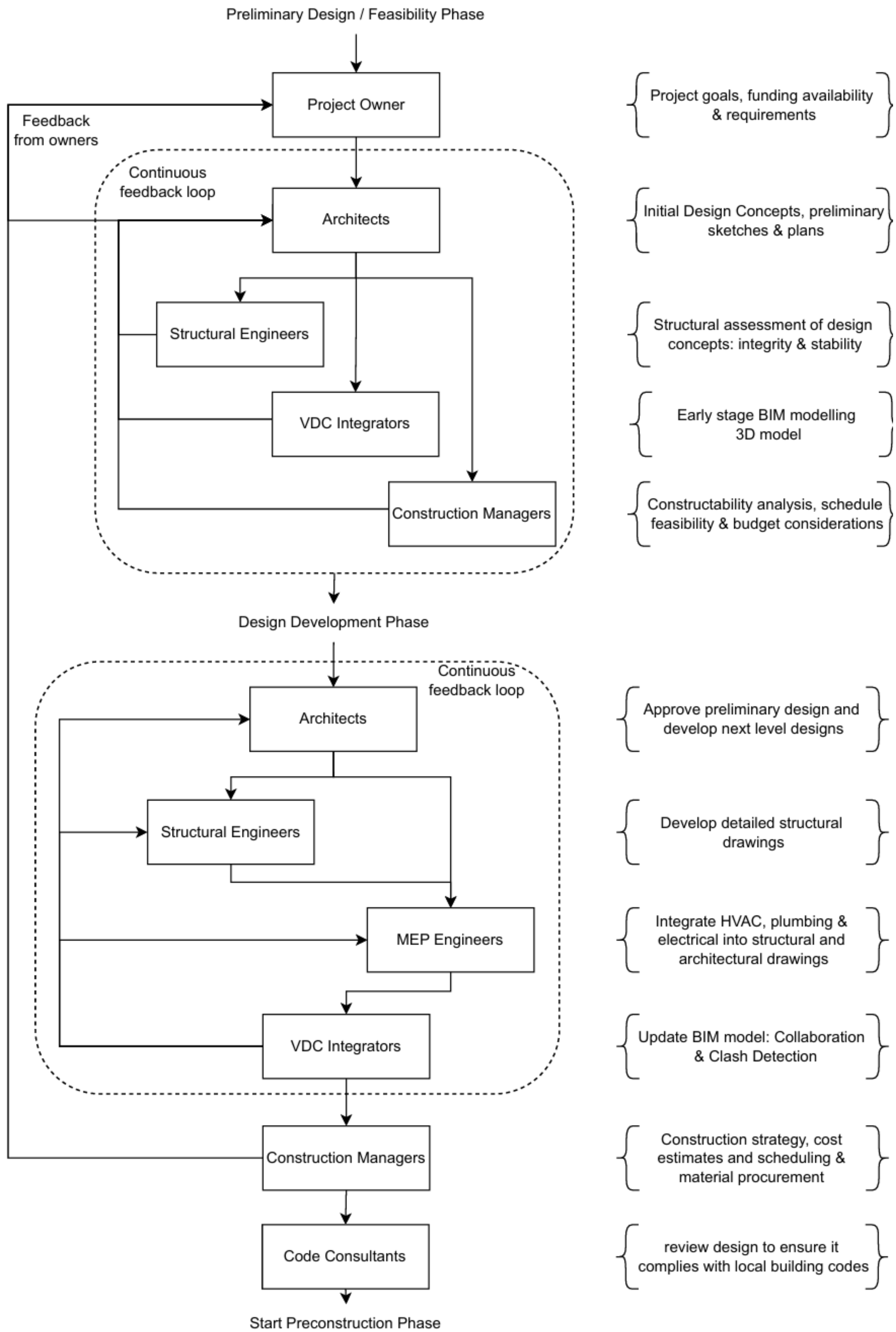


*Figure 19 Information Flow Mapping for Preliminary Design and Design Development Phase*

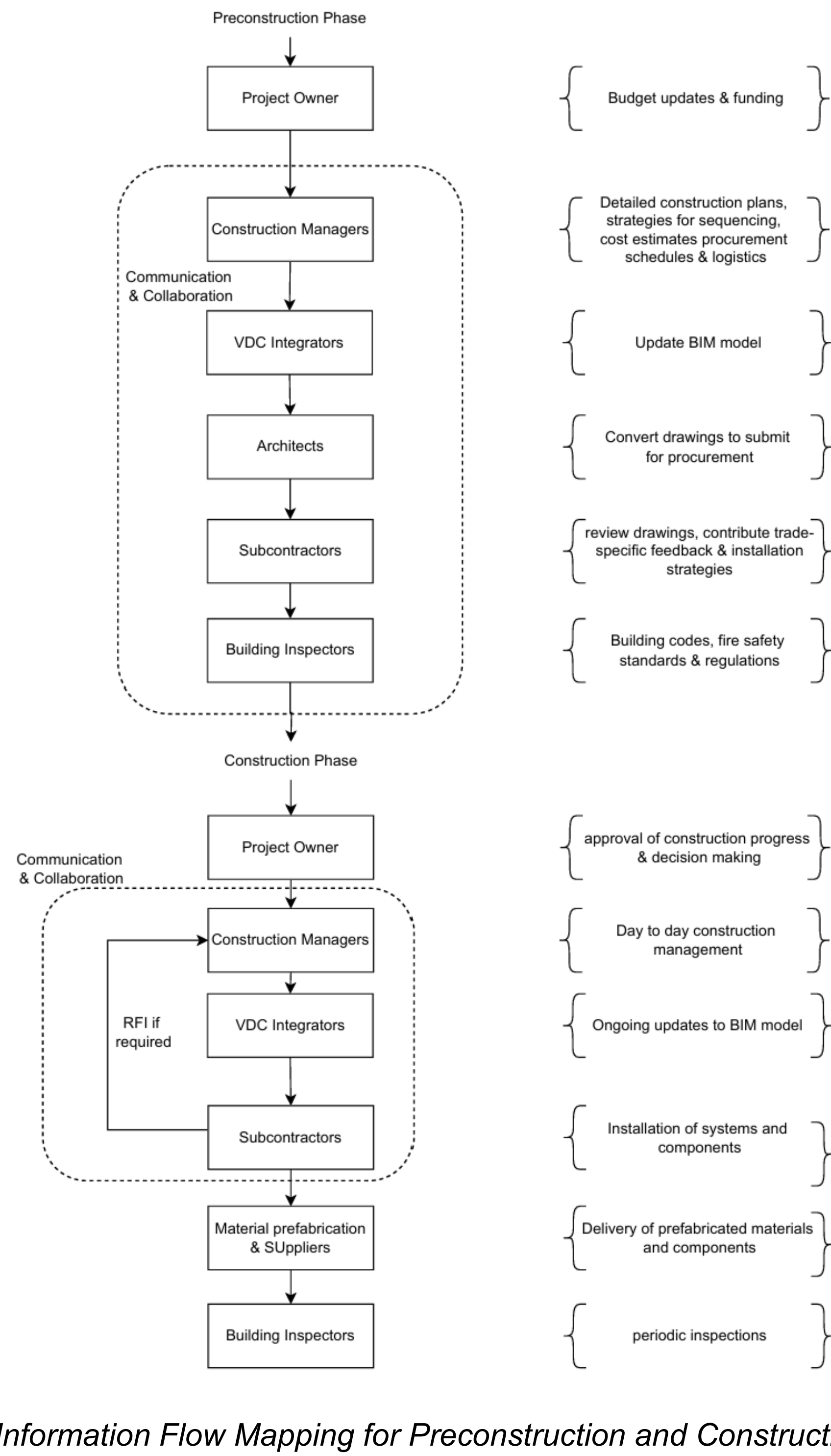


*Figure 20 Information Flow Mapping for Preconstruction and Construction Phase*

**Data Verification**

Interview: Subject 1

The first interview provided critical feedback on the communication links in the preconstruction phase of the information flow model. The interviewee emphasized that subcontractors should have a direct communication channel with VDC Integrators and other stakeholders, rather than relying on the General Contractor (GC) or Construction Manager (CM) as an intermediary. They highlighted that requiring all communication to pass through the GC/CM can create delays, misinterpretations, and inefficiencies in resolving design clarifications and compliance-related queries.

Instead, establishing a direct link between subcontractors and key stakeholders would streamline coordination, improve response times, and enhance collaboration, particularly in addressing technical challenges early in the project. While structured oversight from the GC/CM remains important for maintaining project accountability, the interviewee suggested that direct engagement should be encouraged where it optimizes workflow and reduces bottlenecks in the preconstruction phase.

Interview: Subject 2

The second interview reinforced the feedback from the first interview, agreeing that direct links between subcontractors and VDC Integrators in the preconstruction phase are necessary. This validation confirmed the hierarchical communication flow through the General Contractor (GC) or Construction Manager (CM) via RFIs.

Additionally, the interviewee suggested further refinements to the information flow model:

1. Phase Consolidation: Proposed merging the Preliminary Design and Design Development phases into a single "Predesign Phase" to streamline early-stage activities like approval and initiation. However, this suggestion will be verified in future interviews before making any changes to the research model.
2. Key Stakeholders: Recommended including Installers and Fabricators as critical stakeholders in the preconstruction and construction phases, highlighting their roles in material preparation and on-site assembly.
3. Building Inspection & Regulation Bubble: Suggested moving the "Building Inspection & Regulation" bubble from the preconstruction phase to the

construction phase, as these stakeholders are not typically involved after the design development phase until construction begins.

These insights have been partially incorporated into the revised model. While the inclusion of Installers and Fabricators and the repositioning of the Building Inspection & Regulation bubble improves the model's alignment with industry practices, the phase consolidation proposal will undergo further validation before implementation.

Interview: Subject 3

The third interview was conducted with a group comprising a senior project manager and a field engineer, offering insights from both managerial and on-site perspectives. This discussion provided valuable feedback on the preconstruction phase and highlighted practical challenges faced during mass timber projects.

1. Direct Communication with Architects: The interviewees noted that, during the preconstruction phase, they often needed to directly communicate with the architect to clarify design details. This feedback indicates the necessity of including a communication link between the project management team and architects in the preconstruction phase of the model.
2. Late Notification of Changes: A significant challenge highlighted by the interviewees was the late notification of design or scope changes by the General Contractor or Designer. This issue becomes particularly problematic when other contractors, such as those who handle concrete or steel, are involved, as it creates delays and misalignment between teams.

These insights underscore the importance of timely communication and notification processes in mass timber projects. Based on this feedback, additional considerations will be made to reflect direct communication pathways and emphasize the role of proactive notification mechanisms in the preconstruction phase.

Interview: Subject 4

The fourth interview was conducted with a VDC Manager who provided insights into the dynamics of team involvement in mass timber projects operating under a Construction Manager at Agency contract model. This type of contract involves distinct team compositions across different phases of the project lifecycle, reflecting a structured and phased approach to team integration.

1. Preliminary Design Stage: At this stage, the project team is limited to the Constriction Manager, Designer and Owner. The focus is on setting project goals, aligning initial design concepts, and assessing feasibility.
2. Design Development Stage: During this phase, the VDC team and MEP teams are integrated into the project. Their addition ensures better coordination of design details, clash detection, and preparation for downstream workflows.
3. Preconstruction Stage: In this phase, the project team expands to include Subcontractors, Installers, and fabricators, and other specialized teams. This stage focuses on finalizing construction plans, refining sequencing strategies, and ensuring readiness for execution.
4. Communication Practices: To maintain clarity and alignment across the various teams, weekly meetings were conducted three times per week involving multiple stakeholders. These meetings played a critical role in ensuring information was consistently transferred, issues were addressed promptly, and coordination across teams remained seamless throughout the project phases.

This phased integration approach, combined with frequent cross-team meetings, highlights a clear structure for collaboration and information flow. These insights emphasize the importance of both structured team involvement and regular communication practices for reducing misalignment and ensuring successful execution of mass timber projects.

Interview: Subject 5

The fifth interview was conducted with an Erector who provided insights into the importance of early-stage involvement of construction-phase stakeholders in mass timber projects. Drawing from his experience in the construction stage, the interviewee emphasized the critical role of erectors and manufactures in ensuring smoother project execution through proactive participation during the design phase. This perspective highlights the need for a collaborative approach to align design intent with practical construction feasibility and reduce potential challenges during execution.

1. Early involvement of Erectors and manufactures: The interviewee emphasized that erectors and manufactures should be involved early in the design process.

Early engagement ensures that the design process runs smoothly and minimizes the number of change orders.

2. Benefits of Early Involvement: Aligns the design with intent with construction feasibility, reducing potential conflicts during execution. This enhances clarity during the construction phase, as stakeholders involved in the design process understand the project better.
3. Improved Collaboration: The interviewee highlighted that having the same person or team involved throughout the design and construction stages fosters better coordination and communication. Proactive collaboration between designers, manufacturers, and erectors ensures that the design is practically executable, avoiding delays or misunderstandings during construction.
4. Post-Project Review and feedback: Stressed the importance of conducting a review after each project to evaluate the process and outcomes. Back-and-forth information exchange between stakeholders after project completion helps improve design collaboration for future projects. These reviews contribute to continuous improvement and better results in mass timber project execution.

Interview: Subject 6

The sixth interview was with a material supplier, he emphasized the critical role of suppliers in the early stages of mass timber projects. Engaging suppliers early allows for better decision-making on material selection, design coordination, and logistics management, reducing inefficiencies and unexpected delays later in the project.

The supplier highlighted five key aspects that make it easier to communicate with stakeholders when suppliers are involved from the start:

1. Material Selection: Early supplier involvement ensures that project teams understand the available mass timber options, helping them choose the most suitable materials based on structural requirements, budget, and sustainability goals.
2. Connection Design Optimization: Suppliers can provide input on the best fastening and connection solutions, ensuring efficient assembly and compatibility with prefabricated components.

3. Lead Time Management: Suppliers can provide accurate material availability and lead time estimates, helping project teams plan procurement and scheduling more effectively.
4. Transportation & Logistics: By involving suppliers in planning discussions, project teams can optimize delivery schedules, storage solutions, and on-site handling, reducing material damage and waste.
5. Design Assist Contracts: Some suppliers participate in design assist contracts, which allow them to review drawings, suggest optimizations, and recommend alternative materials, improving constructability and cost efficiency.

Additionally, the interviewee pointed out a common misconception that not all manufacturers are suppliers. Manufacturers are only involved when a project requires specialized or custom mass timber products, while most projects rely on readily available, standardized mass timber materials from suppliers. This distinction is essential for project teams to streamline procurement and avoid unnecessary delays.

Interview: Subject 7

The seventh interview was conducted with a professional from a company specializing in connectors and fasteners for mass timber projects, who also has a strong structural background. The discussion focused on the critical role of early involvement in the design development phase, the importance of standardization connection systems, and addressing logistical and structural challenges unique to mass timber construction. Their insights provided valuable perspectives on improving collaboration, optimizing connection designs, and incorporating feedback mechanisms for continuous improvement in future projects.

1. Early Involvement in Design Development Phase

The interviewee emphasized the importance of involving suppliers of connectors and fasteners during the design development phase. Early engagement allows suppliers to collaborate with designers and recommend connection solutions that align with structural requirements. This proactive approach helps minimize potential challenges during construction, ensuring smoother execution and reducing the likelihood of rework.

2. Standardization of Connection Systems

The need for standardized connection systems was highlighted as a critical factor in mass timber projects. Standardization streamlines the installation process and ensures compatibility between prefabricated components, fabricators, and installers. By adopting standardized systems, project teams can achieve better coordination and reduce variability in construction workflows.

3. Logistics and Lead Time of Connectors

The interviewee stressed the importance of addressing logistics and lead time for manufacturing and delivering connectors. Early engagement with suppliers ensures that project teams can plan procurement and inventory effectively, avoiding delays caused by material shortages. This logistical alignment is critical to keeping mass timber projects on schedule.

4. Removing Code Consultants from the Design Development Phase

The interviewee suggested removing Code Consultants from the design development phase, stating that structural engineers are sufficient to ensure compliance with regulatory and structural requirements. This adjustment simplifies the information flow and reflects typical practices where code compliance is handled by the design team.

5. Hiring Consultants for Inspection if Needed

The interviewee emphasized that if the Authorities Having Jurisdiction (AHJ) lack experience in mass timber construction, they should hire specialized consultants to perform inspections during the construction phase. This ensures that compliance and safety standards are met, even in projects involving relatively new construction methods like mass timber.

Interview: Subject 8

The eighth interview was conducted with a professional who has extensive experience in mass timber projects, particularly in log and timber connections. The discussion focused on verifying updates made to the information flow model from previous interviews, with the interviewee affirming that most of the changes were accurate and aligned with the industry practices.

1. Cross-Verification of Changes

The interviewee validated the adjustments made to the information flow model, particularly changes related to stakeholder involvement and communication pathways across various phases. This confirmation reinforces the accuracy and practical application of the revised model in mass timber projects.

2. Importance of Supply Chain Management

The interviewee highlighted the critical role of supply chain management in mass timber projects. Effective supply chain coordination ensures timely delivery of materials, minimizes delays, and reduces the risk of project interruptions. Key aspects include aligning material procurement schedules with construction timelines, optimizing transportation logistics, and maintaining clear communication between suppliers, manufacturers, and project teams. This feedback underscores the need to integrate supply chain considerations into project planning and management workflows.

**Consolidated and Repeated Insights from Interviews**

1. Early Involvement of Stakeholders

Supported by Subjects 5 ,6, and 7:

- Erectors and manufacturers must be involved during the design development phase to ensure smoother design execution, fewer change orders, and better alignment of design intent with construction feasibility.
- Early supplier involvement facilitates material selection, connection design optimization, and lead time management.
- Having the same team involved throughout the project improves coordination and minimizes misunderstandings.

2. Phase Consolidation

Supported by Subjects 2 and 4:

- Proposed merging Preliminary Design and Design Development into a single "Predesign Phase" for better workflow and alignment in the early stages of mass timber projects.
- Early phases focus on setting project goals, aligning initial designs, and assessing feasibility.

3. Stakeholder Integration Across Phases

Supported by Subjects 4 ,5, and 6:

- Design Development Phase: Add VDC teams and MEP engineers to improve coordination, clash detection, and workflow planning.

- Preconstruction Phase: Expand to include subcontractors, installers, and fabricators to refine construction plans and sequencing strategies.
- Communication is vital across all phases, weekly meetings (3x/week) ensure proper information transfer and issue resolution.

4. Communication Flow Refinements

Supported by Subjects 1, 2, and 3:

- Subcontractors should communicate with the GC or CM directly rather than through RFIs with VDC integrators or code consultants, simplifying communication pathways.
- Direct communication with architects during preconstruction is necessary to clarify design details, ensuring alignment before construction begins.

5. Standardization of Connections

Supported by Subjects 7 and 8:

- Standardized connection systems ensure compatibility between prefabricated components, fabricators, and installers, reducing variability and construction delays.
- Design assist contracts can help improve connection designs by involving suppliers early in the design phase.

6. Late Notification of Changes

Supported by Subjects 3 and 5:

- Late notifications of design or scope changes by GCs or designers cause delays and misalignment, especially with subcontractors handling concrete or steel.
- This emphasizes the need for proactive and transparent communication processes throughout the project.

7. Supply Chain Management

Supported by Subjects 6 and 8:

- Effective supply chain management ensures timely material delivery, minimizes delays, and reduces risks.

- Key considerations include material procurement schedules, transportation logistics, and clear communication between suppliers, manufacturers, and project teams.

8. Regulatory Adjustments

Supported by Subjects 7 and 2:

- Remove code consultants from the design development phase, as structural engineers handle most compliance tasks.
- If AHJs lack experience in mass timber construction, specialized consultants should be hired for inspection during the construction phase.

9. Post-Project Review

Supported by Subjects 5 and 6:

- Conduct post-project reviews to document lessons learned, challenges faced, and recommendations for improvement.
- Create a feedback loop for future projects, enhancing design collaboration and supply chain efficiency.

| Topic | Mass Timber | Conventional | Recommendation |
| --- | --- | --- | --- |
| Installer & Fabricator Involvement | Early Team Input | Late-Stage Involvement | Involve Early |
| Team Coordination Meetings | Weekly Coordination | Biweekly Coordination | Regular Meetings |
| Post-Project Review | Common Practice | Familiar Practice | Encourage Reviews |
| Lead Time Planning | Long Lead Times | Readily Available | Early Procurement |
| Connection Systems | Non-Standardized | Standardized Details | Standardize Connections |
| Supply Chain Coordination | Needs Early Planning | Flexible Logistics | Plan Supply Chain Early |
| Code/Inspection Involvement | Early Contact | Familiar Processes | Engage Early |
| Prefab Sensitivity | High Design Accuracy | On-Site Adjustments | Use BIM Early |

*Figure 21 Key Differences between Mass Timber and Conventional Construction*

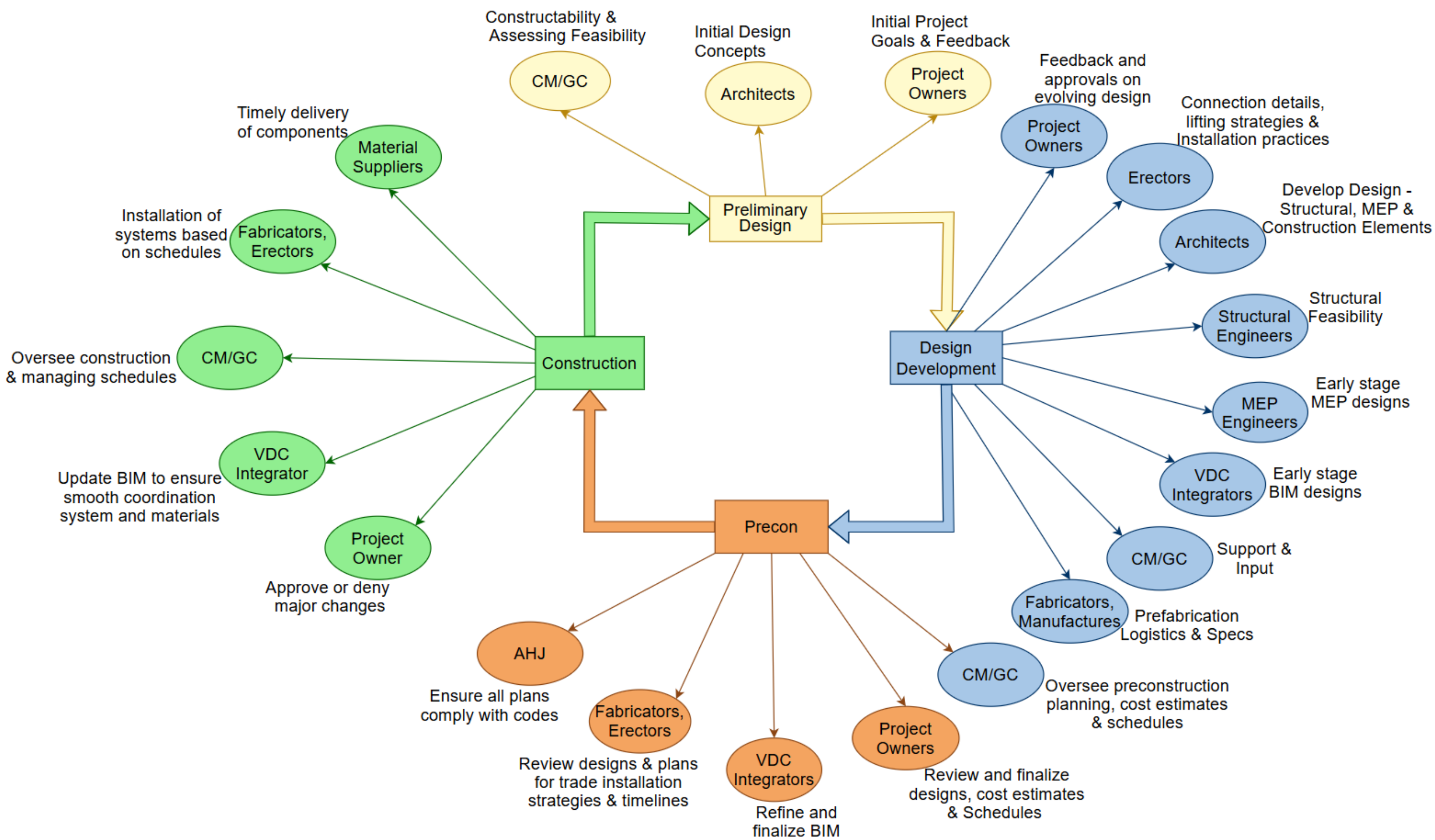


*Figure 22 Heart of the model*

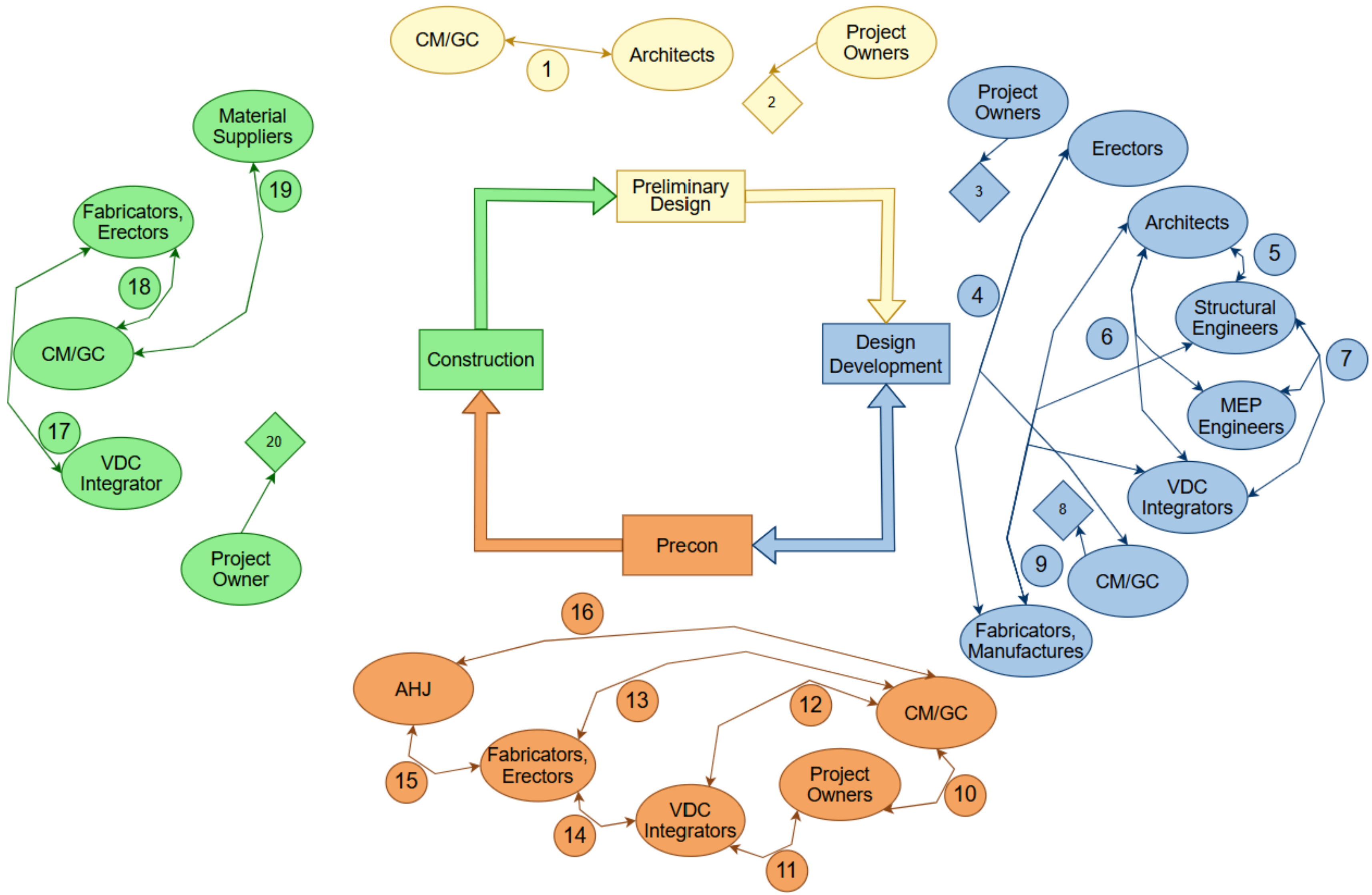


*Figure 23 Informaiton Flow Refined Diagram*

Numbers in the Diagram

1. Constructability and Cost Estimates
2. Initial Project Goals and Feedback
3. Central Feedback and Approval
4. Provide input on connection details, lifting strategies, and installation feasibility to minimize on-site issues.
5. Design Integrity and Stability
6. Initial Drawings of HVAC, Plumbing & Electrical
7. Resolve clashes, optimize sequence, and initial BIM models
8. Coordination with all teams for smooth process
9. Shop drawings for materials, prefabrication logistics, and ensure mass timber specifications align with the design intent
10. Feedback and approval for final construction planning
11. Final approval of BIM model
12. Feedback loop between construction planning and BIM refinement
13. Continuous coordination on schedule, procurement and installation strategies
14. Close collaboration for accurate modelling and clash detection
15. Regulatory feedback on trade system, MEP and fire protection
16. Code compliance check and permit approvals
17. Update BIM models as per as-builts
18. Continuous updates on progress, installation issues and scheduling adherence.
19. Logistics, planning and material delivery coordinates
20. Coordination with all teams for smooth process

Shapes in the Diagram

- Diamond shapes indicate stakeholders who interact with all teams in their phase
- Bidirectional arrows highlight flexibility in design modifications between the Preconstruction and Design Development phases.
- Arrows represent the flow of information among different stakeholders, ensuring seamless collaboration from design to execution.

**Integration of Interview Findings into AI-Assisted Model**

The results from industry interviews provide key insights into the challenges, best practices, and improvements necessary for optimizing project management and information flow in mass timber construction projects. These findings form the foundation for developing an AI-assisted model that automates and continuously updates the information flow model based on real-world project data. While this AI model is an initial attempt to apply AI technology in mass timber construction, it demonstrates the potential for streamlining decision making, improving stakeholder coordination, and enhancing workflow efficiencies.

The key interview results were analyzed, categorized, and structured into critical themes, which were used to train the AI model. These themes represent the core output derived from discussions with industry experts, project managers, structural engineers, suppliers, fabricators, and other mass timber stakeholders. The AI-assisted model integrates these insights to refine project processes and support industry professionals in navigating the complexities of mass timber projects. As this AI model evolves, it can be further developed to align with industry needs and expectations, making it a valuable tool for improving mass timber project execution.

Early Stakeholder Involvement and Its Impact on Project Execution

The interviews strongly emphasized the critical role of early stakeholder involvement, particularly for erectors, manufacturers, and material suppliers. The AI model was trained to prioritize and suggest early engagement strategies, ensuring better coordination and reduced project risks.

- Key AI Training Data: Early involvement of erectors and manufacturers in the design development phase ensures better coordination between design and construction, reducing change orders and execution challenges. Engaging suppliers early optimizes material selection, connection design, and standardization, improving compatibility and installation efficiency. Proactive lead time management helps prevent procurement delays, ensuring smooth project progression.

Phase Consolidation for Better Workflow Management

The Preliminary Design and Design Development phases were proposed to be merged into a single “Predesign Phase” for better workflow efficiency. The AI model was trained to evaluate project phase integration and recommend streamlined early-stage processes.

- Key AI Training Data: The Predesign Phase focuses on Setting project goals, aligning initial designs, Assessing feasibility and constructability

Improved Stakeholder Integration Across Project Phases

A major takeaway from interviews was that stakeholders should be added in a phased manner to improve coordination, clash detection, and workflow alignment. The AI model was trained to map stakeholder involvement across project phases.

- Key AI Training Data: Design Development Phase should integrate VDC teams and MEP engineers for better coordination and clash detection. Preconstruction Phase should expand to include subcontractors, installers, and fabricators for finalizing construction strategies and conduct weekly coordination meetings (2x per week) to improve communication.

Communication Flow Refinements for Efficient Decision-Making

The interviews refined information flow pathways, reducing unnecessary communication between certain stakeholders. The AI model was trained to suggest streamlined communication routes.

- Key AI Training Data: Subcontractors need not communicate via RFIs to the GC or CM rather than directly with VDC integrators or code consultants. Direct communication with architects in the preconstruction phase is necessary to resolve design uncertainties on time before execution.

Standardization of Connection Systems for Improved Construction Efficiency

A consistent issue reported in interviews was the lack of standardization in connection systems, leading to construction delays and inconsistencies. The AI model was trained to identify standardized connection systems and recommend best practices.

- Key AI Training Data: Standardized connection systems enhance compatibility among prefabricated components, fabricators, and installers, reducing variability and streamlining construction. Early supplier involvement through design assist contracts improves connection designs, ensuring efficiency and constructability.

Impact of Late Design or Scope Changes

A major issue affecting MTC project timelines is late notifications of design or scope changes, particularly from GCs or Designers. The AI model was trained to predict change impacts and recommend mitigation strategies.

- Key AI Training Data: Late notifications disrupt project sequencing and create misalignment between trades such as concrete, steel, and mass timber, leading to delays and inefficiencies. Implementing proactive communication mechanisms ensures timely updates, minimizing disruptions and enhancing coordination across all stakeholders.

Supply Chain Management Optimization

Efficient supply chain management is crucial for MTC projects. The AI model was trained to suggest procurement schedules and logistics.

- Key AI Training Data: Aligning material procurement schedules with project phases ensures a seamless flow of resources, preventing delays and disruptions. Effective logistics planning is essential to avoid on-site bottlenecks, optimizing transportation, storage, and handling of materials to maintain project efficiency.

Role of Code Consultants and Regulatory Adjustments

The role of code consultants in design development was reconsidered based on interview feedback. The AI model was trained to recommend regulatory adjustments based on project needs.

- Key AI Training Data: Structural engineers can effectively replace code consultants in the design phase, streamlining the approval process while maintaining compliance with building regulations. However, if Authorities Having Jurisdiction (AHJs) lack experience in mass timber construction, specialized consultants should be engaged during the construction phase to ensure proper inspection and regulatory adherence.

Post-Project Review and Continuous Learning

A structured post-project review model was developed to ensure continuous learning and process improvements. The AI model was trained to incorporate real-time feedback loops.

- Key AI Training Data: Post-project reviews should document lessons learned and suggest workflow improvements and tracks recurring trends and inefficiencies across projects.

**Testing and Verifying the Model – Mass Timber Intelligence**

The AI-Powered Mass Timber Project model is designed to assist industry professionals, including project managers, architects, engineers, fabricators, and suppliers by providing real-time recommendations on workflow optimization, stakeholder coordination, and project execution. By leveraging data-driven insights, the model aims to enhance decision-making, reduce inefficiencies, and streamline information flow throughout mass timber projects.

However, this AI model is in its initial stage and serves as proof of concept for integrating AI into mass timber project management. To ensure continued relevance and accuracy, the model must be updated regularly with new data from completed projects, industry advancements, and evolving best practices. As more feedback is incorporated, the AI's predictive capabilities, recommendation accuracy, and applicability to real-world scenarios can be refined and expanded, making it a valuable long-term tool for optimizing mass timber construction workflows.

The AI model will be trained in structured interview insights and validated industry data to provide highly relevant and accurate recommendations. Below are its core functionalities:

- Early Stakeholder Involvement Recommendations: AI model will provide real-time guidance on when and how stakeholders should be involved at different project phases.
- Workflow Optimization & Information Flow Management: AI model will analyze the project stage and suggest improvements in information flow, ensuring that communication follows structured pathways to prevent misalignment.

- Procurement & Supply Chain Optimization: AI model will suggest best practices for aligning material procurement schedules with project phases, predict lead times, and flag supply chain risks.
- Connection Standardization & Design Assist Integration: AI model will provide recommendations on making connection systems standardize to enhance prefabrication efficiency.
- Risk Mitigation & Late Design Change Prevention: AI model will explain risks related to late design changes and recommend preventive measures for better project sequencing.
- Communication & Coordination Optimization: AI model will suggest communication strategies, including meeting frequencies, coordination checkpoints, and data-sharing protocols to enhance stakeholder alignment.

**Training a GPT Model**

This section presents a collection of critical questions and insights that were identified through industry interviews and research analysis. These questions serve as guiding considerations for mass timber construction (MTC) projects, providing a structured approach to addressing procurement challenges, trade coordination, prefabrication logistics, and schedule optimization. These questions and answers have been instrumental in shaping the AI model's ability to provide project-specific recommendations, optimize decision-making, and enhance stakeholder coordination in MTC projects. Part of the information outlined in this section was used as initial training dataset for the AI model, ensuring that its output aligns with real-world industry practices and project management challenges. As the model evolves, it will continue to integrate updated project data, allowing for continuous learning and refinement of best practices in mass timber construction.

Procurement and Material Supply

Effective procurement planning and supply chain coordination are essential for maintaining project timelines and minimizing risks. The following questions provide insight into how procurement strategies should be structured to support mass timber construction:

- Question: What are the lead times for procuring mass timber components, and how do they align with the construction schedule?
  Answer: Lead times vary based on supplier availability, material selection, and project complexity. Early engagement with suppliers is essential for optimizing procurement schedules and ensuring seamless alignment with construction timelines. Proactive planning reduces the risk of material shortages and project delays.
- Question: How should the procurement schedule be optimized to prevent project delays?
  Answer: A well-structured procurement schedule should align with project phases and incorporate just-in-time (JIT) delivery strategies. Advanced planning, coordinated supplier agreements, and integrating supply chain logistics with project timelines help prevent on-site bottlenecks and disruptions.
- What contingency plans should be in place for potential supply chain disruptions?
  Answer: Strategies such as diversifying suppliers, considering long lead time for critical materials, and implementing flexible scheduling should be established. Risk mitigation plans should include clear communication protocols between suppliers and project teams to handle disruptions swiftly and efficiently.

Coordination Between Trades

Successful execution of MTC projects depends on seamless collaboration between different trades. The following questions highlight the coordination challenges and solutions related to integrating various building systems within mass timber structures:

- Question: What coordination challenges arise when integrating MEP (Mechanical, Electrical, Plumbing) systems into mass timber?
  Answer: The prefabrication process requires precise planning, as modifications to MEP routes after fabrication can be costly and complex. Early collaboration among stakeholders ensures that structural and MEP designs are well-integrated to avoid conflicts.
- Question: How should penetrations in mass timber panels be designed to avoid structural integrity issues?
  Answer: Penetrations should be strategically pre-designed with input from

structural and MEP engineers, ensuring they do not compromise structural stability. Tools like BIM and Virtual Design and Construction (VDC) enable precise modeling of penetrations to avoid clashes and optimize routing.

- Question: What sequencing strategies ensure that mass timber erection does not delay MEP installation?
  Answer: A carefully coordinated installation sequence should be planned during preconstruction to align mass timber erection with MEP work. Scheduling pre-installation meetings and ensuring early resolution of routing conflicts help streamline the workflow and prevent delays.
- Question: How can digital tools (BIM, VDC) be used to pre-coordinate MEP routes and prevent on-site conflicts?
  Answer: BIM and VDC enable early clash detection and coordination of MEP layouts with structural components. These tools allow teams to digitally simulate construction sequences, minimizing potential conflicts before on-site execution.

Prefabrication and Logistics

The prefabrication process offers efficiency and precision in mass timber construction but requires careful planning. The following considerations help optimize off-site fabrication and logistics management:

- Question: What factors should be considered when planning off-site prefabrication for mass timber components?
  Answer: Coordination between designers, fabricators, and contractors is essential to ensure compatibility between prefabricated elements and on-site assembly. Material tolerances, connection details, and pre-installed components should be reviewed before fabrication.

How should the site be prepared to receive and store mass timber deliveries?
Storage areas should be designated to minimize material handling and prevent exposure to moisture. On-site staging must be carefully planned to ensure efficient installation, with deliveries scheduled in phases to reduce congestion.

- Question: What transportation strategies minimize handling damage and optimize delivery schedules?
  Answer: Prefabricated components should be packaged and transported in the

sequence of installation to minimize handling. Protective measures such as bracing and controlled loading/unloading procedures help prevent damage and streamline installation efficiency.

- Question: How does just-in-time delivery impact overall project efficiency?
  Answer: JIT delivery enhances efficiency by reducing material storage requirements and aligning deliveries with the construction schedule. However, it requires strong coordination with suppliers and transportation teams to avoid disruptions.
- What role do crane logistics play in the sequencing of mass timber panel installation?
  Answer: Strategic crane planning optimizes lifting sequences, reducing unnecessary material handling. Crane positioning, access routes, and installation sequences should be planned to ensure safe and efficient placement of mass timber panels.

Construction Schedule Optimization

The integration of mass timber with other construction materials and building systems must be carefully sequenced to avoid project delays. The following questions address scheduling challenges and process optimization strategies:

- Question: What are the most common causes of schedule delays in mass timber construction, and how can they be mitigated?
  Answer: Late design changes, supply chain disruptions, and coordination challenges are primary causes of delays. Implementing structured preconstruction planning, early stakeholder involvement, and proactive communication strategies minimizes risks.
- Question: How should mass timber installation be sequenced relative to other trades to maximize efficiency?
  Answer: Mass timber components should be installed in coordination with MEP trades to ensure that penetration and routing conflicts are resolved before placement. Early subcontractor engagement and weekly coordination meetings improve efficiency.

- Question: What alternative construction methods (hybrid approaches) can be explored to optimize the schedule?
  Answer: Hybrid approaches such as integrating concrete cores for structural stability while utilizing mass timber for floors and walls can accelerate project timelines. Prefabricated hybrid connection systems improve installation speed and reduce on-site labor.
- Question: How does prefabrication impact the overall critical path of the project?
  Answer: Prefabrication shifts construction activities off-site, reducing on-site labor requirements and weather-related risks. Effective logistical coordination and just-in-time delivery are crucial to keeping the project on schedule.

This structured set of questions from the model forms the basis for continuous learning in mass timber construction management. The AI-driven approach ensures that knowledge gained from completed projects is systematically applied to future developments, enhancing efficiency, reducing risks, and improving stakeholder collaboration. The post-project review framework captures new challenges and insights, allowing the AI model to refine its recommendations over time.

**Post Project Review Analysis**

The post-project review analysis was developed to ensure continuous learning and process improvement in mass timber construction (MTC) project management. By integrating AI-driven automation, the framework enables stakeholders to document challenges, track communication inefficiencies, and refine workflows based on real-world feedback. This structured approach ensures that lessons learned from completed projects are systematically captured, analyzed, and used to enhance future MTC projects.

The review system is designed to standardize post-project evaluations by collecting insights from project owners, contractors, engineers, architects, suppliers, and fabricators. Stakeholder’s document key challenges related to design coordination, procurement, logistics, and regulatory compliance, ensuring that knowledge gained from one project is preserved for future applications. Communication gaps are also analyzed to identify inefficiencies in information flow, allowing for improvements in stakeholder collaboration.

An auto-updating information flow model has been implemented to dynamically integrate post-project data. This AI-assisted system continuously refines team coordination structures and communication pathways based on empirical findings. By tracking changes in industry best practices and real-world project outcomes, the model evolves to ensure optimal workflow management in future mass timber projects. The system ensures that project execution strategies remain relevant, efficient, and adaptable to emerging challenges.

The AI-powered trend analysis feature further strengthens the review framework by detecting recurring project challenges and identifying areas for improvement. Through pattern recognition and historical project analysis, the AI model generates data-driven recommendations on optimizing scheduling, procurement, design coordination, and risk management. This ensures that repeated mistakes are minimized, and best practices are reinforced across mass timber projects.

The expected impact of the framework is significant, as it enhances stakeholder coordination and decision-making processes. AI-driven insights provide project managers, designers, and suppliers with tailored recommendations that improve efficiency and reduce errors. The structured feedback loop ensures that knowledge is continuously refined and reapplied, promoting a more proactive approach to mass timber project execution. By leveraging data-driven learning cycles, the construction industry can achieve higher efficiency, reduce costs, and enhance sustainability in mass timber projects. Finally, scalability and long-term applicability are central to this framework’s success. The auto-updating AI model ensures that industry knowledge remains current and adaptable to new developments in materials, regulations, and project delivery methods. The framework provides a scalable solution for mass timber adoption, setting a foundation for continuous growth and improvement in MTC project execution. Future enhancements could include real-time data collection tools, predictive analytics, and AI-driven decision support systems, further strengthening its role in optimizing project management.

**Post Project review Analysis Template**

This template serves as a structured framework for conducting a post-project review analysis in mass timber construction projects. The information gathered from professionals who have actively participated in these projects will provide critical insights into stakeholder coordination, supply chain logistics, scheduling, and overall project execution. These collected data points will be used to update and refine the GPT model, ensuring that it continuously learns from real-world experiences and improves its ability to provide accurate recommendations and project management support.

Project Name:

Project Location:

Project Value:

Project Completion Date:

Delivery Method (IPD, DB, CM, DBB, etc.):

1. General Project Information

- Project Type (Commercial, Educational, Residential, etc.):
- Primary Mass Timber Components Used (CLT, Glulam, NLT, DLT, etc.):
- Primary Structural System (Hybrid, Full Timber, Steel-Timber, Concrete-Timber, etc.):

Major Stakeholders Involved:

- Owner/Developer:
- Architect:
- Engineer:
- General Contractor:
- Suppliers/Fabricators:

2. Project Execution & Scheduling

- Were there any major schedule delays? (Yes/No)
- If yes, what were the main causes?
- How was mass timber installation sequenced relative to other trades? (Describe sequencing order and any observed conflicts)
- How did prefabrication impact the overall construction schedule? (Was it beneficial, neutral, or did it create additional challenges?)

3. Stakeholder Coordination & Communication

- How effective was early stakeholder involvement in resolving project challenges?

- Did weekly coordination meetings help streamline communication and prevent issues? (Yes/No) If no, what challenges were faced? ________________
- What were the major communication gaps identified between teams?

4. Supply Chain & Logistics
   - Were there supply chain disruptions that impacted project execution? (Yes/No). If yes, what were the key issues?
   - How effective was Just-in-Time (JIT) delivery in minimizing storage issues?
   - What were the lessons learned in optimizing material procurement and logistics?
5. Connection Design & Structural Performance
   - Were there any challenges with mass timber connection design and execution? (Yes/No). If yes, what were the key issues? (Check all that apply)
   - How effective was early supplier involvement in optimizing connection designs?
6. Regulatory & Compliance
   - Did regulatory approvals and code compliance processes create delays? (Yes/No). If yes, what were the key issues?
   - Should code consultants be more involved in future mass timber projects? (Yes/No)
   - If No, who should oversee compliance verification? (Structural Engineers, Regulatory Bodies, Other)
7. Post-Project Learnings & Future Recommendations
   - What were the biggest takeaways from this project that should be improved in future mass timber projects?
   - Would you recommend any changes to the project delivery method for similar projects? (Yes/No, and Why?)
   - Any additional comments or recommendations for improving mass timber project execution?

# CHAPTER 5: CONCLUSION AND FUTURE RESEARCH SCOPE

## Overview

Chapter 4 summarized the key findings of this research, detailing the challenges, insights, and proposed solutions for improving project management practices and information flow in mass timber construction (MTC) projects. It provided an in-depth analysis of stakeholder coordination, procurement logistics, scheduling, regulatory challenges, and digital tool integration. The chapter also introduced the development of an AI-assisted model and a post-project review framework, which were designed to streamline decision-making, risk assessment, and continuous learning in MTC.

This study initially aimed to verify Objective 3 by comparing the developed information flow model with existing project management software used in mass timber projects. However, findings from industry interviews revealed no significant drawbacks in current project management software tools that would necessitate model validation through this approach. Instead, a new research direction emerged organically, leading to the development of an AI-based decision-support model that could automate knowledge extraction, optimize workflow efficiencies, and enhance project coordination in MTC projects.

This AI-driven approach represents an initial attempt at incorporating advanced automation into mass timber project management. While this model is in its early stages, it has the potential to scale and evolve into a more sophisticated tool, supporting stakeholders across multiple project phases. The post-project review framework further strengthens this research by ensuring that lessons learned from completed projects are systematically captured and used to refine future mass timber project execution.

By integrating AI-assisted automation and structured post-project analysis, this study not only advances digital transformation in MTC but also lays a foundation for future research that can explore more scalable AI solutions, enhanced automation techniques, and deeper industry-wide adoption of AI in mass timber project management.

## Summary of Research Outputs

This research was structured around three primary objectives, each contributing to the understanding and improvement of project management practices in mass timber construction (MTC) projects. The findings from literature review, industry interviews, and

AI model development led to significant insights and proposed solutions, which are summarized below:

The first objective focused on mapping the key phases of mass timber projects Preliminary Design, Design Development, Preconstruction, and Construction while identifying the stakeholders involved and the flow of information between them. Through literature review and real-world project analysis, an initial framework was developed, outlining hierarchical team structures, roles, and stakeholder responsibilities.

The second objective involved creating detailed flow diagrams that map how information is exchanged between stakeholders at each stage of an MTC project. Developed initial flowcharts based on theoretical models, which were then validated through semi-structured interviews with industry professionals. Key findings from the industry validation process revealed bottlenecks in decision-making, inconsistencies in information exchange, and misalignments in communication between trades. The interviews also confirmed that weekly coordination meetings, BIM tools, and proactive regulatory engagement are essential to maintaining an effective information flow. The validated information flow model now provides a structured representation of stakeholder interactions, decision-making points, and critical communication pathways. This output serves as a guiding framework for future MTC projects, helping project teams enhance coordination and reducing inefficiencies across different phases.

The third objective originally aimed to validate the refined information flow model using existing project management software tools. However, industry interviews revealed no significant gaps in current software applications. Instead, this led to the organic development of an AI-assisted model, designed to enhance decision-making, automate knowledge extraction, and continuously refine project processes based on real-world feedback. This AI model was trained on key insights from industry interviews and structured project data, allowing it to offer intelligent recommendations, identify inefficiencies, and improve workflow coordination in mass timber projects. Additionally, a Post-Project Review Framework was introduced to ensure continuous learning and optimization. This framework systematically collects lessons learned, tracks recurring challenges, and updates the AI model, ensuring that past experiences contribute to improved project execution in future mass timber projects. By integrating AI-driven automation and structured post-project review analysis, this research has provided a foundational step toward digital transformation in mass timber construction project management. The results demonstrate that AI can complement traditional management practices, enabling mass timber projects to become more efficient, data-driven, and adaptable to industry needs.

**Conclusions**

This research aimed to improve project management practices and streamline information flow in mass timber construction (MTC) projects by addressing key inefficiencies in stakeholder coordination, procurement, and digital tool integration. Through a comprehensive literature review, industry interviews, and AI model development, the study identified and tackled challenges that impact MTC projects, ultimately leading to the creation of structured methodologies and technological solutions.

One of the major conclusions drawn from this study is that effective stakeholder engagement and structured communication frameworks are crucial for optimizing mass timber projects. The findings demonstrated that early involvement of suppliers, fabricators, and erectors in the design and preconstruction phases significantly improves coordination, reducing errors and construction delays. Additionally, supply chain disruptions and logistical challenges were identified as major contributors to project inefficiencies, emphasizing the need for proactive procurement planning and just-in-time (JIT) delivery strategies.

Furthermore, the research validated the necessity of post-project review mechanisms in mass timber construction. Despite the industry's increasing reliance on Building Information Modeling (BIM) and other project management software tools, there was no clear indication from industry professionals that existing software solutions were inadequate. Instead, the research led to the development of an AI-assisted model as a new approach to addressing knowledge management gaps and decision-making inefficiencies in MTC projects.

This study represents an initial attempt to integrate AI-driven automation in mass timber project management, particularly in post-project review analysis and information flow optimization. The AI model developed in this research acts as an intelligent knowledge repository, continuously learning from project data and updating information flow models based on evolving industry challenges. The findings demonstrate the potential of AI in enhancing mass timber project workflows, offering a scalable framework that can be refined and expanded upon in future research.

**Research Contributions**

This research makes several significant contributions to the fields of construction management, mass timber construction (MTC), and AI-driven decision-making, with a particular focus on improving information flow, stakeholder coordination, and post-project review analysis. The study was driven by insights gained from industry interviews, which played a key role in shaping the final outcomes, including the development of an AI-assisted model and a structured post-project review framework.

Key Contributions Based on Industry Interviews

- Stakeholder Coordination and Early Involvement: The interviews emphasized the need for early engagement of stakeholders such as erectors, manufacturers, and suppliers in the design development phase to improve constructability, reduce rework, and minimize delays. The findings led to recommendations for integrating suppliers into early decision-making processes, ensuring better alignment between design intent and material procurement strategies.
- Supply Chain and Procurement Challenges**:** The research identified major supply chain disruptions as a significant challenge in MTC projects, including material delays, vendor coordination issues, and transportation inefficiencies. Based on industry feedback, a structured procurement optimization strategy was developed, highlighting the importance of just-in-time (JIT) delivery and contingency planning to mitigate delays.
- Communication and Information Flow Refinements**:** Several interviews highlighted gaps in stakeholder communication, particularly between subcontractors, VDC integrators, and design teams. The study mapped these communication gaps and refined the information flow model to reflect hierarchical decision-making processes and critical information exchange points in MTC projects.

Validation of Project Management Software in Mass Timber Construction

The initial intent was to validate the effectiveness of existing project management software in MTC projects, but interviews did not reveal significant deficiencies in digital tools. Instead, the findings highlighted the lack of structured knowledge management and process optimization, leading to the organic development of an AI-assisted model.

AI-Assisted Model for Information Flow Optimization

The AI-assisted model was designed to auto-update and refine the information flow model based on real-world project data. This model was trained using key insights from interviews, allowing it to provide project-specific recommendations on workflow optimization, risk mitigation, and stakeholder coordination. The AI system enhances decision-making in MTC projects by detecting patterns in project execution, predicting inefficiencies, and recommending process improvements.

Integration of AI in Post-Project Review Analysis

The research introduces a structured post-project review framework, enabling continuous learning and adaptation of MTC best practices. The AI model automates the post-project review process by analyzing past project data, identifying recurring challenges, and generating recommendations for improving stakeholder coordination and project efficiency. This approach ensures that lessons learned from completed projects are systematically documented, processed, and applied to future MTC projects.

**Future Research Scope**

This study has laid a strong foundation for improving project management in mass timber construction (MTC) through structured methodologies, AI-assisted analysis, and post-project review frameworks. However, several areas require further exploration to enhance the scalability, adaptability, and integration of AI-driven solutions into MTC workflows. Future research can focus on the following key areas:

Enhancing the Post-Project Review Framework

- AI-Powered Knowledge Retention and Retrieval: Future studies can focus on expanding AI's ability to retain and retrieve knowledge from past projects to improve decision-making in new projects.

- Development of a Standardized Post-Project Review Model: Researchers should work on creating an industry-wide standardized framework for post-project analysis in MTC, ensuring structured learning from completed projects.
- Automated Lesson-Learned Databases: AI-based models can be designed to collect, categorize, and analyze post-project feedback, making it easier to identify trends, issues, and best practices.

Optimization of Stakeholder Coordination and Information Flow

- AI-Based Decision Support Systems for Project Teams: Future research should develop AI-powered decision-support systems that provide real-time recommendations for project managers, contractors, and suppliers, ensuring smoother execution.
- Dynamic Information Flow Models: The information flow model can be refined by automating updates based on stakeholder interactions and integrating AI-driven insights to optimize communication paths.
- AI-Assisted Collaboration Between Design and Construction Teams: AI models can improve coordination between designers, structural engineers, and fabricators by predicting potential conflicts before construction begins.

AI and Project Management Software in Mass Timber Construction

- Evaluating AI Integration with Existing PM Software: Instead of replacing project management tools, AI can be integrated with software like Procore, Autodesk BIM 360, or Primavera P6 to enhance reporting, scheduling, and risk assessment.
- Customization of AI for Different Delivery Methods: Further research can analyze how AI models can adapt to different construction delivery methods, making them more versatile in real-world applications.

Conclusion

Future research should focus on advancing AI's role in mass timber construction by refining post-project review frameworks, enhancing stakeholder coordination, and improving project execution efficiency. AI integration in construction is still in its early stages, and as the technology matures, its ability to drive smarter, more efficient, and sustainable mass timber projects will significantly increase. By addressing current gaps in AI adoption, standardization, and real-time integration, future studies can revolutionize construction management and accelerate the industry's transition toward data-driven decision-making.

**Discussion on Research Impact**

This research has made significant contributions to improving project management in mass timber construction (MTC) by addressing challenges in stakeholder coordination, supply chain management, and information flow optimization. The study introduced AI-assisted solutions and a post-project review framework to enhance decision-making and continuous learning in MTC projects.

Impact on the Mass Timber Construction Industry

- Stakeholder Coordination: Early involvement of erectors, manufacturers, and suppliers improves constructability, reduces rework, and minimizes scheduling conflicts.
- Supply Chain Management: Identifies risks in procurement, optimizes just-in-time (JIT) delivery, and ensures proactive planning to prevent supply chain disruptions.
- Communication Flow: Provides a structured framework for better collaboration between project teams, reducing miscommunication and improving decision-making.

Technological Impact – AI in Construction Management

- AI-Driven Project Optimization: The AI model enhances decision-making, workflow efficiency, and risk management in MTC projects.
- Automated Post-Project Learning: AI ensures that lessons learned from past projects are systematically captured and applied to future projects.
- Predictive Insights: AI detects patterns, inefficiencies, and risks to improve project planning and execution.

Academic Contributions

- New Information Flow Model: Defines stakeholder interactions and decision-making pathways in MTC projects.

**Summary**

This research has contributed to improving mass timber construction (MTC) management by addressing key industry challenges through structured methodologies and AI integration. It has focused on

- Structuring stakeholder coordination
- Developing an AI model for optimizing decision-making
- Creating a post-project review framework for continuous learning
- Validating industry challenges through real-world data
- Laying the foundation for future AI applications in construction

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## APPENDIX 1: INTERVIEW RESULTS

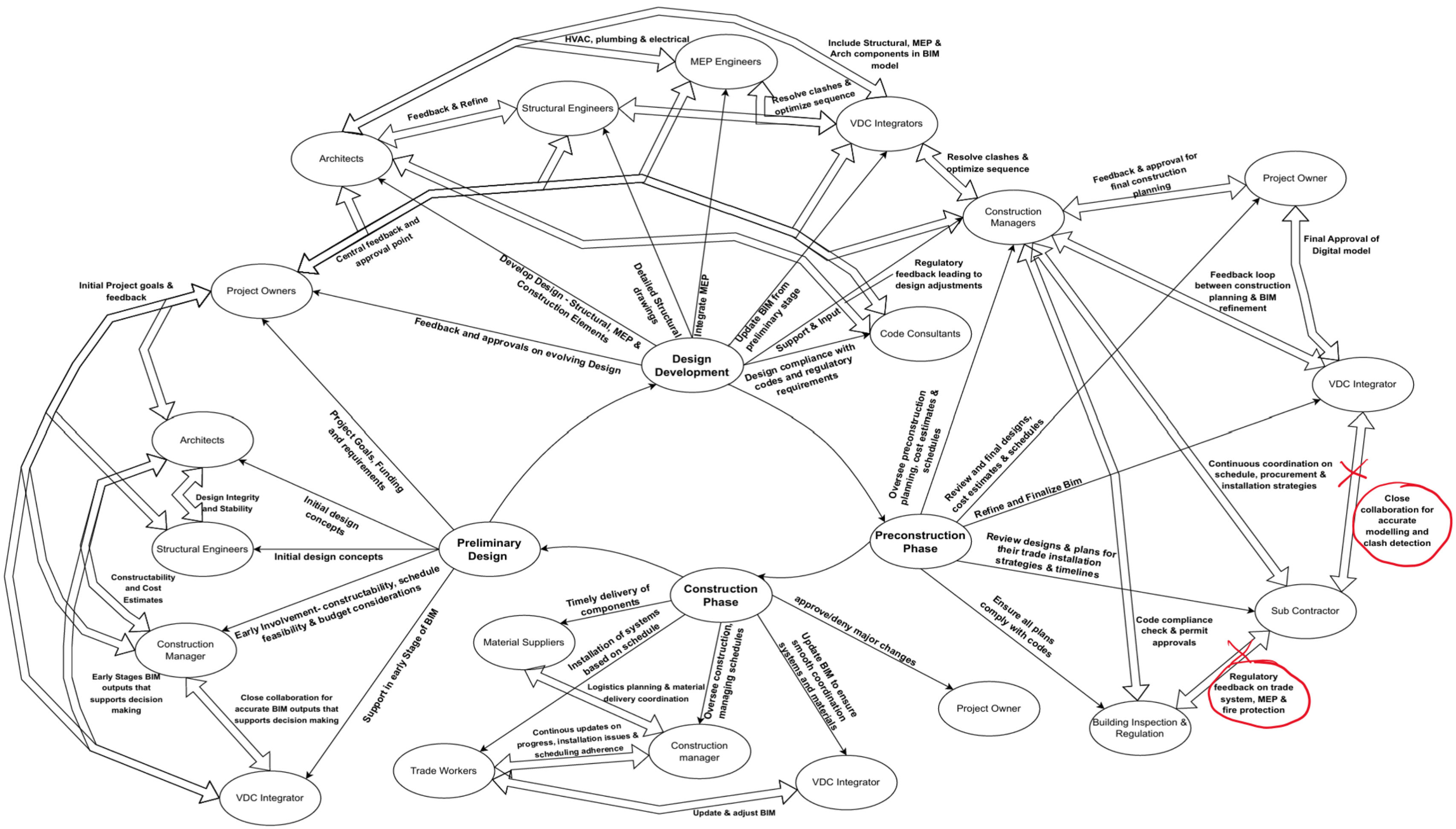


*Figure 24 Recommendations from first Interview*

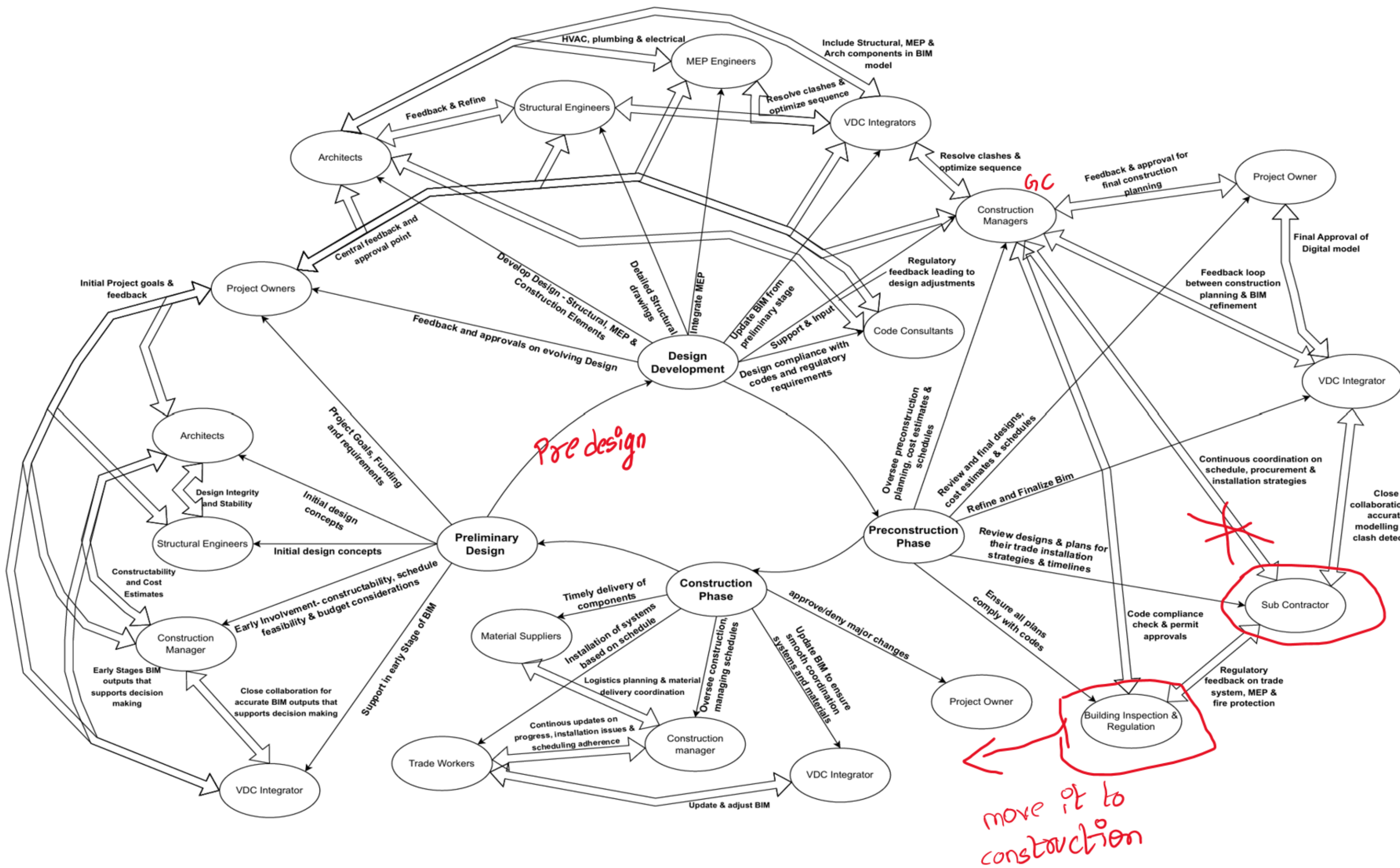


*Figure 25 Recommendations from Second Interview*

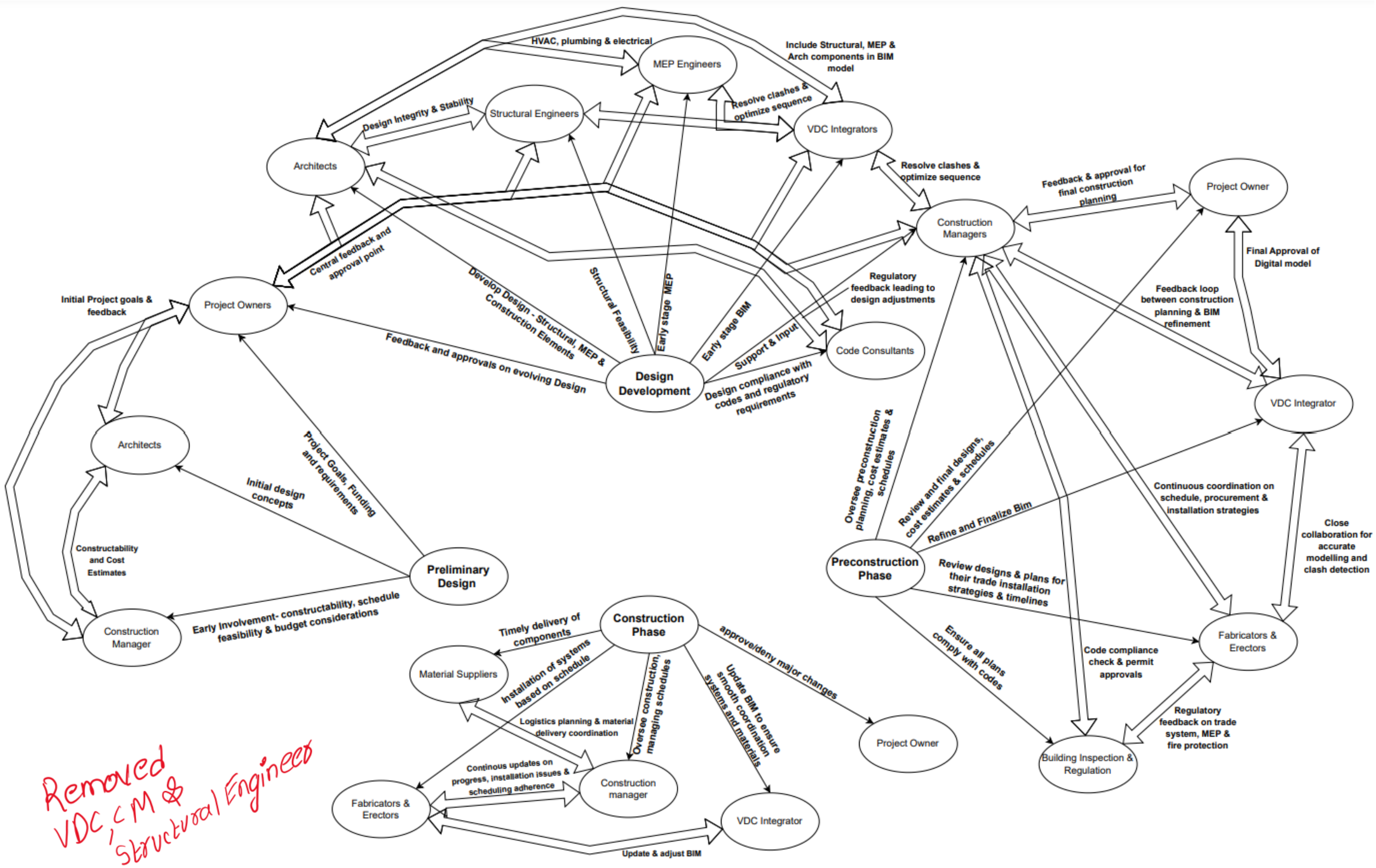


*Figure 26 Recommendations from Fourth Interview*

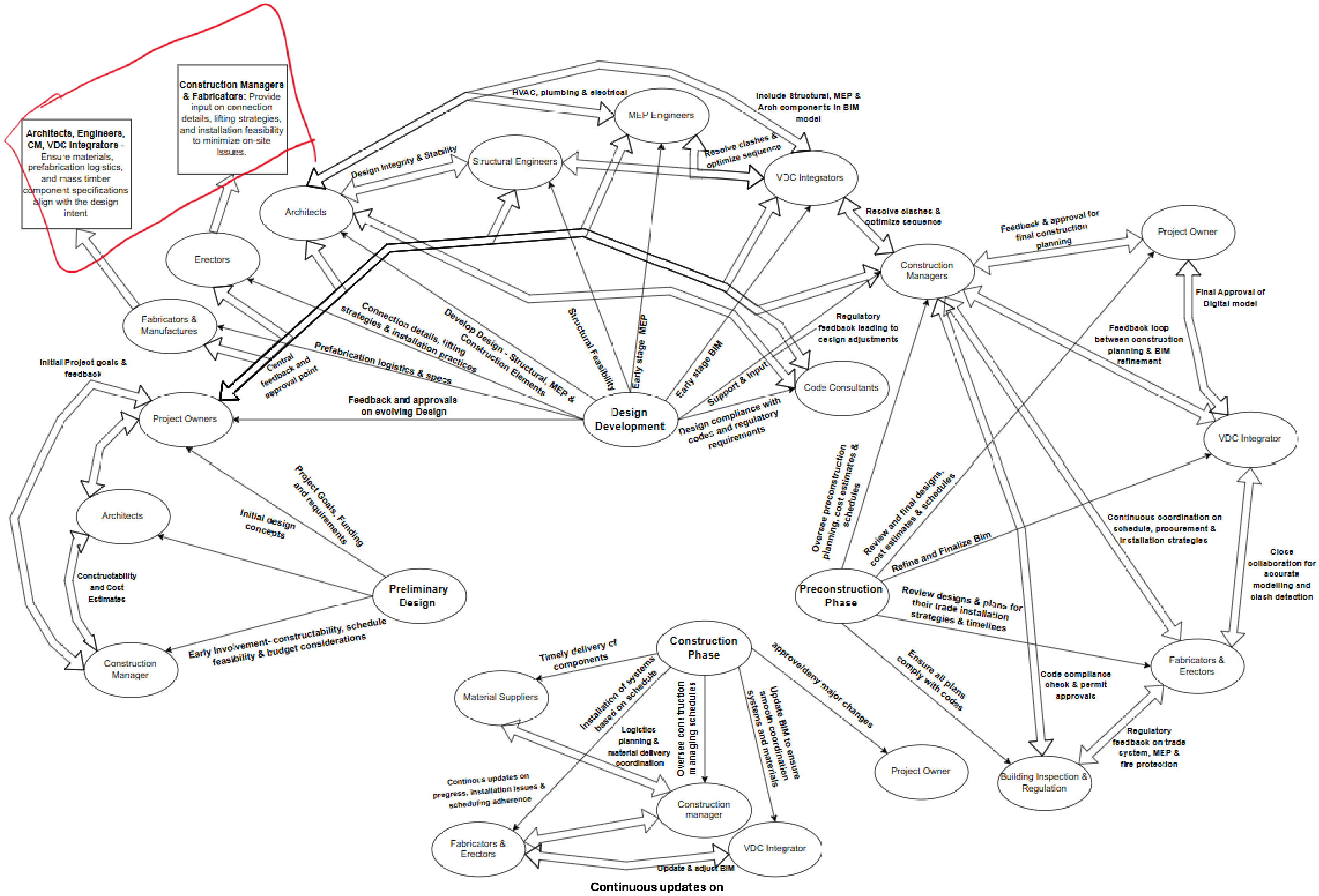


*Figure 27 Recommendations from Fifth Interview*

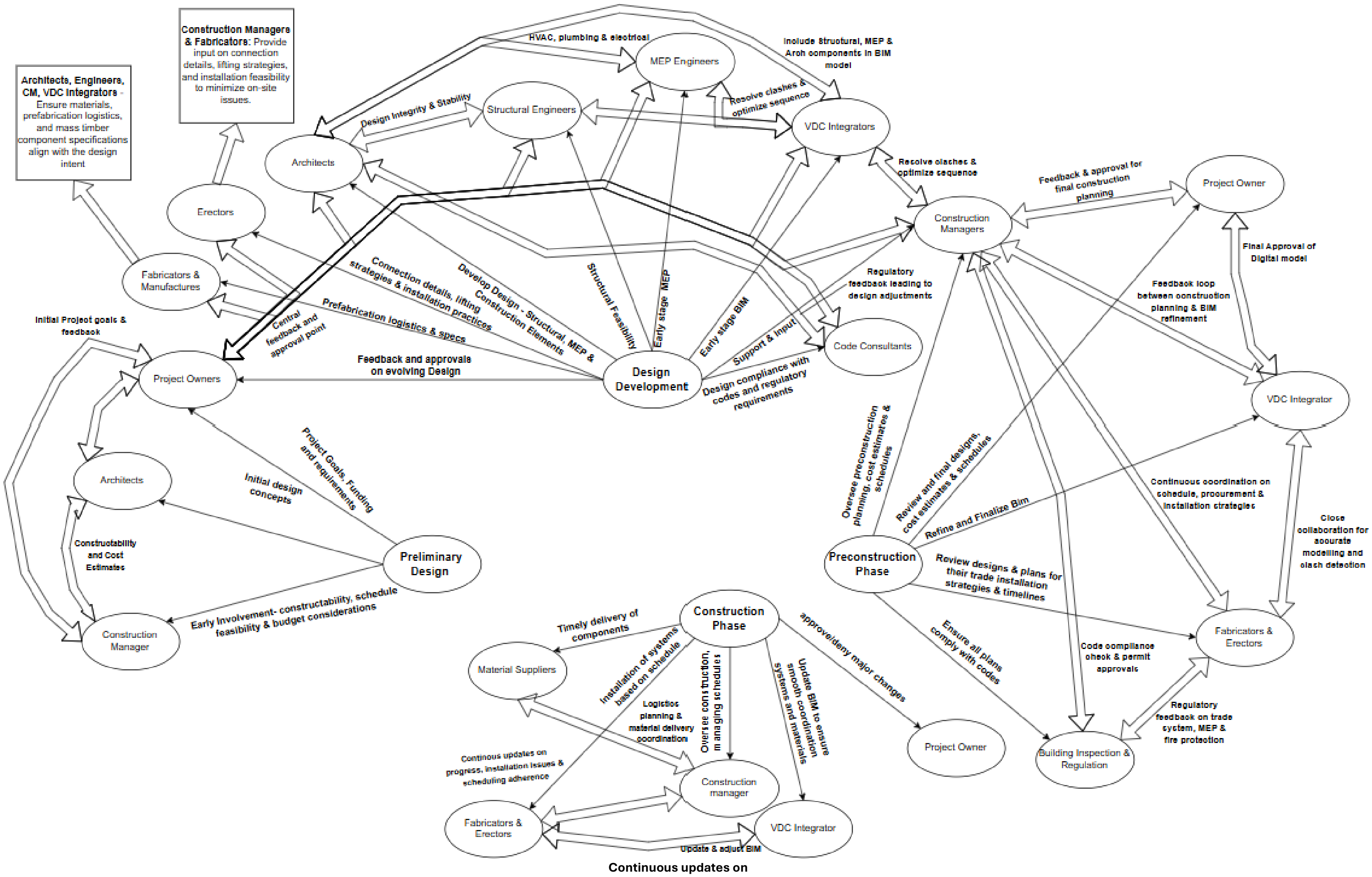


*Figure 28 Recommendations from Sixth Interview*

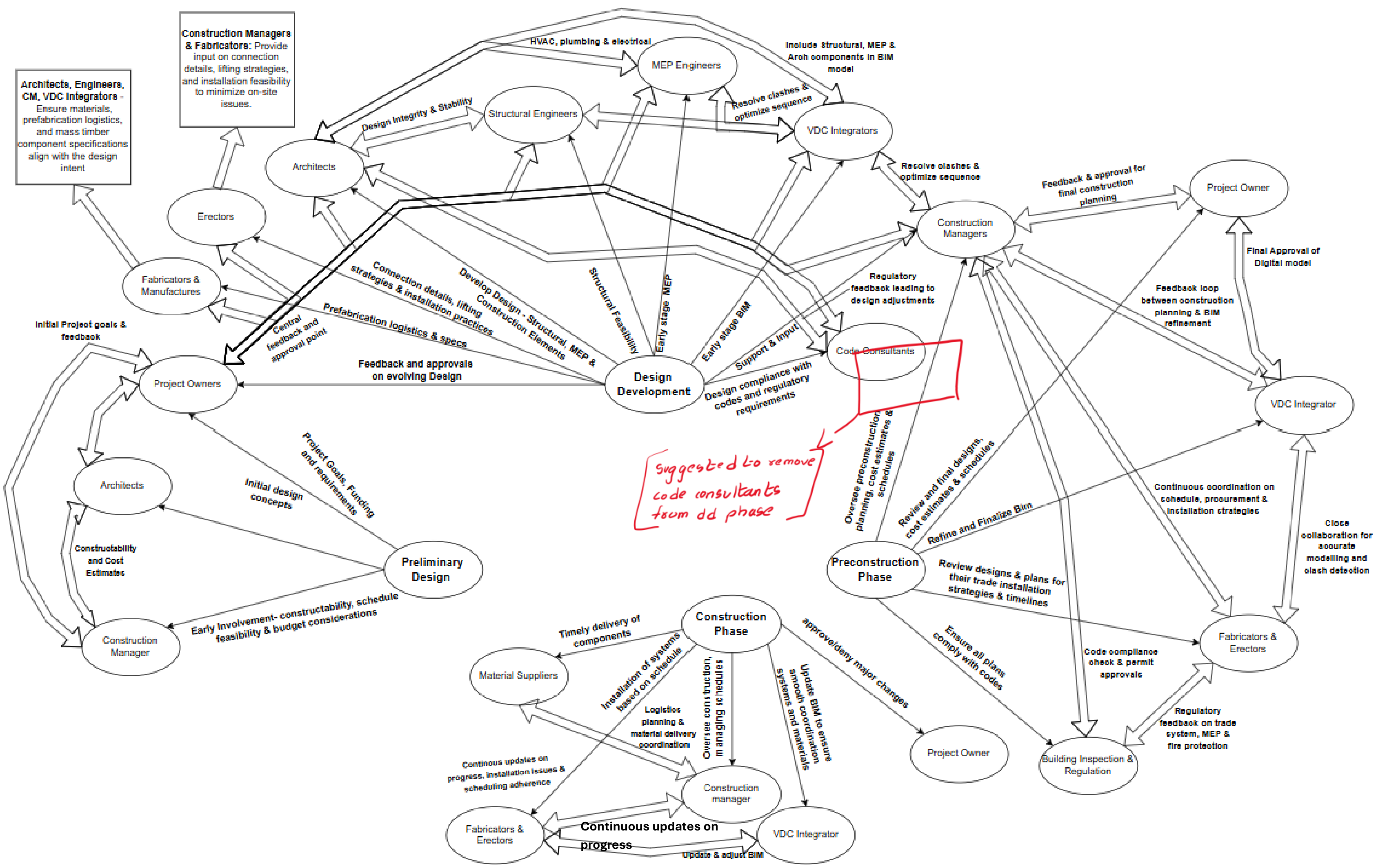

*Figure 29 Recommendations from Seventh Interview*

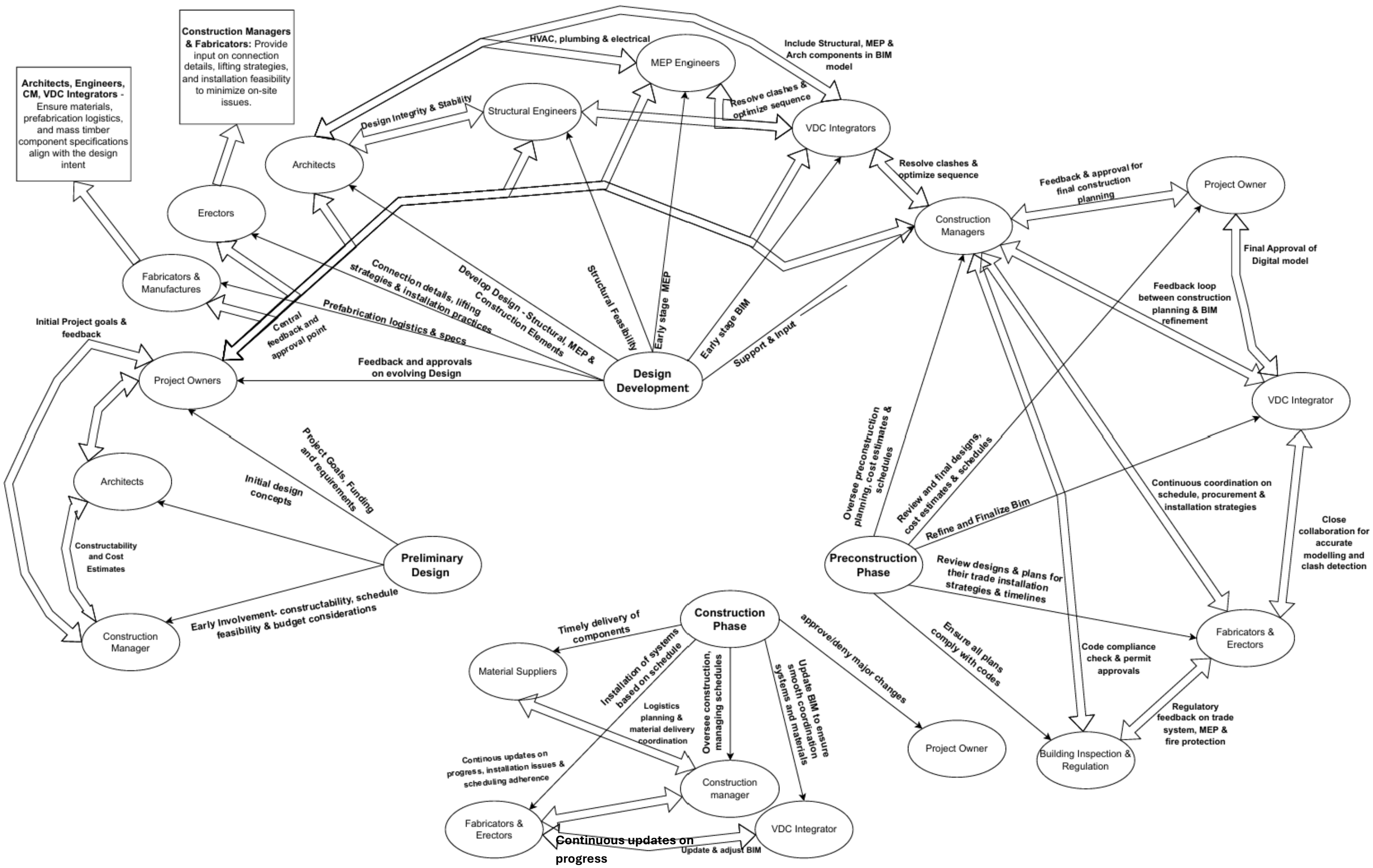


*Figure 30 Final figure after all change*